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FLEAS

Final Report

30 September 1984

Submitted To:

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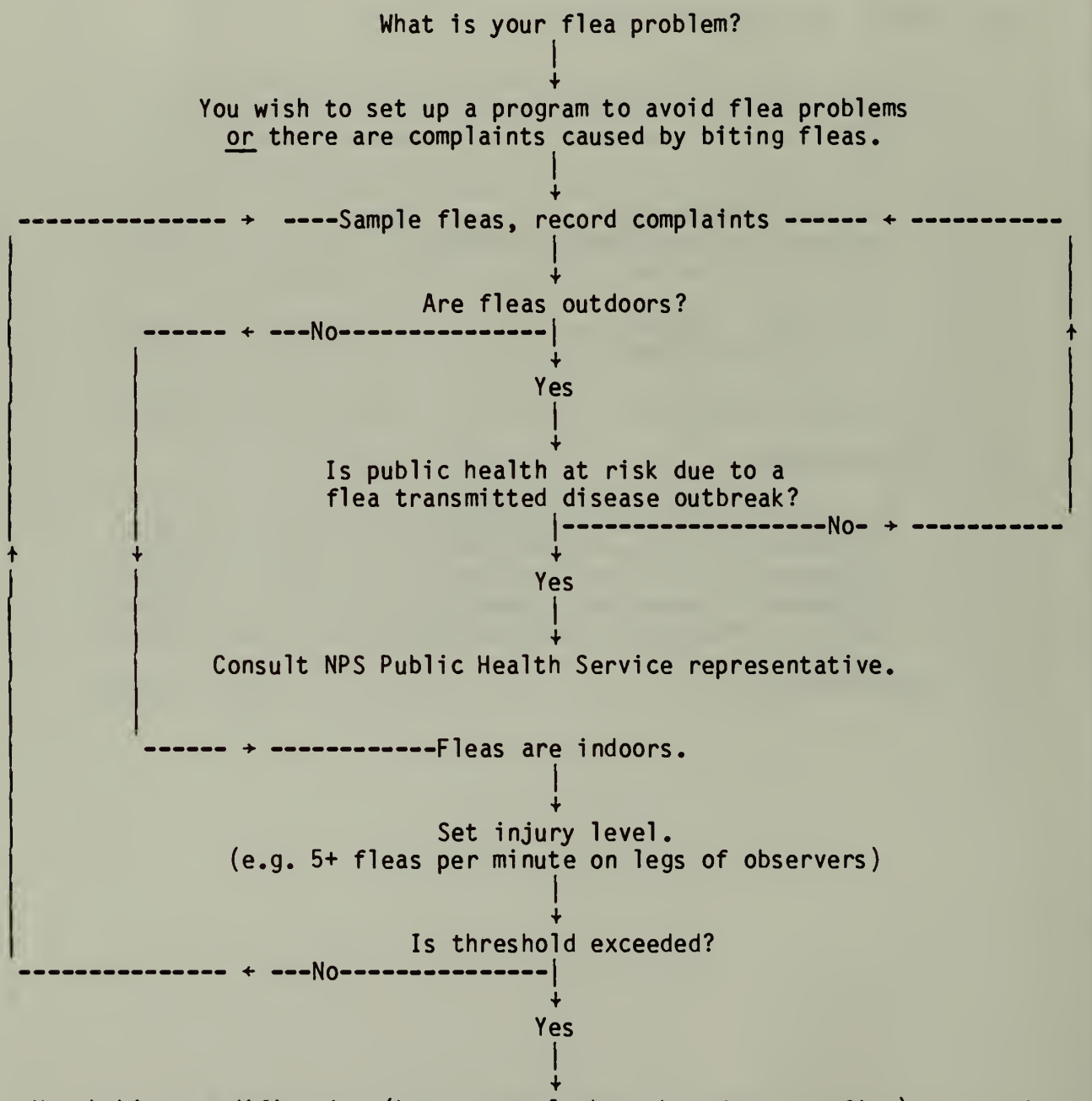
CONTENTS

Section:		Page:
I.	FLEA IPM DECISION TREE	XI-2
II.	BIOLOGY AND ECOLOGY OF FLEAS	
	1. Species Described	XI-3
	2. Geographic Distribution	XI-3
	3. Habitat	XI-3
	4. Hosts	XI-3
	5. Life Cycle	XI-4
	6. Seasonal Abundance	XI-5
	7. Responses to Environmental Factors	XI-5
	8. Medical Importance	XI-5
	8.1 Direct Effects	XI-5
	8.2 Indirect Effects	XI-5
	9. Natural Enemies	XI-6
III.	FLEA MANAGEMENT	
	1. Population Monitoring Techniques	XI-7
	2. Threshold/Action Population Levels	XI-7
	3. Management Alternatives - Nonchemical	XI-8
	4. Management Alternatives - Chemical	XI-8
	5. Summary of Management Recommendations	XI-9
IV.	BIBLIOGRAPHY	XI-10

I. FLEA IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticide must conform to the Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


What is your flea problem?
You wish to set up a program to avoid flea problems or there are complaints caused by biting fleas.
Sample fleas, record complaints
Are fleas outdoors?
No
Yes
Is public health at risk due to a flea transmitted disease outbreak?
No
Yes
Consult NPS Public Health Service representative.
Fleas are indoors.
Set injury level.
(e.g. 5+ fleas per minute on legs of observers)
Is threshold exceeded?
No
Yes
Use habitat modification (host removal through rodent proofing), vacuuming, pet treatments, treatment of pet or animal bedding, or approved pesticides.

I. BIOLOGY AND ECOLOGY OF FLEAS

Species Described:

Although there are over 250 species of fleas described in North America (Pratt, 1957), only a few are commonly encountered by humans with enough frequency to be considered pests (Ehman & Story, 1982).

A. Cat Flea - *Ctenocephalides felis* (Bouche')

B. Dog Flea - *C. canis* (Curtis)

C. Human Flea - *Pulex irritans* L.

D. Oriental Rat Flea - *Xenopsylla cheopis* (Rothschild)

Other species such as the rabbit flea (*Cediopsylla symplex* [Ba er], mouse flea (*Ctenopsyllus segnis* [Bosc.]),squirrel flea (*Orchopea howardii* [Baker]), and the ground squirrel flea (*Diamanus montanus* [Baker]), may achieve pest status when their host mammals nest in or near structures or the fleas attack hunters and hikers. Some, such as the northern rat flea or ground squirrel flea are important vectors of sylvatic plague and murine typhus.

See page 167-174 of U.S. Department of Health, Education, and Welfare (1967), for pictorial keys to common fleas of the United States.

Geographic Distribution:

A. Cat Flea - Abundant in eastern United States and far western U.S. Most common flea on cats and dogs.

B. Dog Flea - Throughout U.S. Same range as cat flea.

C. Human Flea - Most common in mid-West, South, and Pacific Coast

D. Oriental Rat Flea - Common in seaports, associated with Norway and roof rats.

Habitat:

Outdoors, fleas are found in mammal and bird nests. Indoors, fleas are often found in pet bedding and in the nests of small mammals behind walls or in other areas.

Hosts:

Adult fleas are external parasites of warm blooded animals (mammals and birds). Most species parasitize mammals and prefer one species.

5. Life Cycle:

Females deposit eggs in groups of 1-18 on the host after a blood meal. Some species such as the cat flea can deposit up to 25 eggs per day and over 1000 in a lifetime. Eggs soon drop off or are brushed off. Due to their spherical or oval shape, they roll into cracks and crevices on the floor or in or near nests and bedding. Eggs are whitish, and 0.5 mm in diameter. Eggs hatch in 2-21 days.

Larvae are approximately 1.5 mm when first hatched, white, and have fine hairs. They lack legs or eyes but possess biting mouthparts. Most species feed on dried blood from the host (in the form of adult flea feces) or organic debris present in cracks and crevices. They also feed on cast larval skins. Depending on the availability of food, relative humidity, and other environmental factors, larvae pass through 3 stages (instars) in one week to several months. Optimal conditions for larval development are temperatures of 65°-80°F (18°-27°C) and 50%-92% relative humidity. Larvae pupate within cocoons spun from silk and may be covered with debris.

The pupal stage usually lasts aproximately 1 week. The newly emerged adult may remain in the cocoon for some time, but under adverse conditions, up to a year may be spent in the cocoon. Emergence occurs in response to pressure applied to the cocoon or detection of host warmth, vibrations, or carbon dioxide (CO_2) in the host's breath.

Adult fleas are small, brownish insects flattened from side to side, without wings but with powerful jumping legs. Adults may live for several years and go without feeding for months at a time under extreme conditions. Fleas may remain in a structure long after the host mammals have been removed. Depending on the species and environmental conditions adults may breed from 2 weeks to 2 years after emerging. Adults feed on blood, and females deposit eggs only after a blood meal. Most species remain on the host only long enough to feed. Nearly all species have host preferences but are not restricted to any one host species. This trait is responsible for the transmission of several diseases from one host species to another (i.e., plague or murine typhus) from rats to humans. Adults prefer warm humid places and will leave a host if it dies.

. Seasonal Abundance:

Outdoors, fleas are most abundant during humid, rainy summers and are more common outside in the southern U.S. than in the North. Indoors, warmth and high relative humidities are condusive to large populations. The sudden appearance of large numbers of adult fleas in mid summer and fall ("flea seasons") is due in large part to the onset of higher humidities and temperatures which permit larval development to accelerate. Larvae may undergo arrested development in less than favorable conditions.

. Responses to Environmental Factors:

As noted above, warm humid environments are favored by fleas. Larval fleas are unable to regulate water loss due in part to the thin exoskeleton. Larval mortality is high in areas where humidity is low and temperatures are high. Fleas are seldom pest problems in such areas.

. Medical Importance:

8.1 Direct Effects:

Flea bites vary in effect from short-lived itching weals to an overall rash, to symptoms which may last over a year, depending on the sensitivity of the victim. Young children are more sensitive than older persons.

Commonly, a small red spot appears where the skin has been pierced. Little swelling ensues, but the spot is accompanied by a red "halo" of irritated skin which usually lasts for several hours to a day.

8.2 Indirect Effects:

Fleas are vectors of several diseases important to human health including plague, murine typhus, and tularemia.

The oriental rat flea is the most important plague vector from rodents (primarily rats) to humans, but at least 30 other flea species can also transmit the disease including the northern rat flea, dog flea, cat flea, and the human flea. Plague (in the sylvatic form) is endemic in the western U.S. among small rodents such as chipmunks and ground squirrels.

Nearly all known cases of plague in humans in the U.S. since 1925 have been associated with wild rodents (mostly from the Rocky Mountain states) and their fleas. An average of 6 cases per year are reported. Periodic epizootic outbreaks occur, resulting in massive mortalities among wild rodents and displacement of disease-carrying fleas to other hosts. The greatest threat to humans will exist when domestic rats are exposed to infection from wild rodents in areas adjacent to human communities.

Murine typhus is a mild form of epidemic typhus which is usually spread by the human louse. The Norway rat population is the main reservoir to the disease. It is most common in the Southwestern and Gulf States, but may be spreading northward. The disease is commonly spread from rat to rat, and from rat to human by the oriental and northern rat fleas. It has also been transmitted by cat fleas from infected feral cats.

Fleas are also vectors of tularemia, a disease related to plague. The natural reservoirs of tularemia are cotton tail rabbits in the East, and jack rabbits in the West. Most cases are from hunters.

Fleas can also be intermediate hosts of several species of tapeworm including species which parasitize humans, dogs, and cats.

9. Natural Enemies:

Fleas are preyed upon by ants and several beetle species which feed on larvae in the hosts' nests (Fox and Bayona, 1968).

III. FLEA MANAGEMENT

1. Population Monitoring Techniques:

Fleas can be monitored in several ways; the simplest is to count and collect fleas landing or crawling on an observer's lower legs for 1 minute. In making surveys, trousers should be tucked into white socks to prevent bites and make collecting easier (socks can be put on over shoes). Light-colored trousers are preferred to provide greater contrast and facilitate counting and collection. A variation on the above is to wrap fly paper (sticky side out) around the lower legs and count fleas adhering after a predetermined interval (Cole & Burden,1978).

Fleas can also be collected by using a light source as an attractant. A light bulb or candle is placed in the center of a square of sticky paper or a bowl of water to which a small amount of detergent (to destroy surface tension) has been added. Fleas attracted to the light are caught on the paper or drowned in the bowl where they can be collected and counted later.

Fleas may also be combed off animals for an index of animal infestation.

An animal may be placed in a plastic or zippered bag with its head outside. Carbon dioxide (CO_2) or insecticide is introduced into the bag. Fleas which fall off the animal are collected as well as fleas which are combed off the animal over a white surface (Ehmann and Storey, 1982).

Pet bedding should be periodically checked for "salt and pepper" (flea eggs and dried-blood feces of adult fleas) which is indicative of infestation. Larvae and pupae can be found at the edge of pet bedding or animal nests.

2. Threshold/ Action Population Level:

In areas where plague is endemic (i.e., Southwestern U.S.) efforts should be made to keep humans and fleas (in this case their wildlife hosts) separate. Camping and other outdoor activities should be restricted especially during an outbreak when fleas seek other hosts. Check with Public Health Service officials if your area is affected.

Indoors, 5 or more fleas on the legs of observers in less than 1 minute is indicative of severe infestation.

In most other cases, fleas are considered pests due to the nuisance caused by their bites.

Decisions on control should be made on a case by case basis.

3. Management Alternatives - Nonchemical:

Fleas require warm blooded hosts to develop and for egg maturation. Elimination of suitable habitat for wild rodents and other animals near structures will often reduce flea population levels. Screening of foundation vents to prevent animals from resting under structures, elimination of vegetation and other rodent harborage, as well as rodent proofing of structures will reduce flea levels.

Indoors, all pet bedding and sleeping areas should be carefully examined for fleas and washed if necessary. Cracks and crevices should be vacuumed and sealed, especially the area between the baseboard and floor. Vacuum cleaner bags should be discarded to prevent reinfestation. If possible, indoor humidity should be lowered to below 50% or as much as possible to kill larvae.

4. Management Alternatives - Chemical:

The following pesticides are registered for use against fleas (Schwartz, 1982):

Silica aerogel
Carbaryl (5% dust)
Precor
Pyrethrins
Resmethrin

Treat floors and baseboards; dust rugs thoroughly, paying particular attention to pet beds and loafing areas. Spray rugs and furniture lightly, vacuum before treatment. Silica aerogel such as Dri-die 67® is often used to treat crawlspaces, wall voids, and attics.

Pets and other animals may be bathed or dusted with a material containing a pesticide or flea repellant. Collars impregnated with insecticides, such as tempephos or dichlorvos which kill or repel fleas, have been used with variable success. Several such materials are commercially available. Fleas on wild mammals have been controlled by placing insecticide in burrows or at bait stations where wild mammals receive a dusting while they are feeding.

Methoprene, an insect growth regulator (IGR) is a synthetic hormone which prevents certain insects from maturing properly, causing lethal complications during pupation.

Methoprene is registered for fleas in two formulations: an aerosol fogger which includes chlorpyrifos as an adulticide; and an emulsifiable concentrate (EC) formulation of methoprene only. It is marketed for use by pest control operators (PCOs) under the trade name Precor®. Methoprene is also available to the general public under the trade name Strike Flea Ender®, and to veterinarians as Vet-Chem Syphatrol-10®. A formulation for use in rodent burrows (in areas where flea-borne disease is endemic) and incorporating an adulticide, is currently being tested.

Methoprene is registered for use in food areas (David Sullivan, Product Manager, Zoecon Corporation, personal communication).

Methoprene does not affect adult fleas or pupae. Effects begin 2 weeks after application when treated larvae begin to pupate. Control is for 3 months or more with each treatment.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Exclude wild mammals and their fleas by rodent proofing all structures.
2. Eliminate harborage for hosts from around structures.
3. Vacuum cracks and crevices especially the areas between baseboards and floors to remove eggs and larvae.
4. Bathe or dust all pets and other domestic animals with commercial flea treatments.
5. Treat floors, rugs, furniture, pet bedding, and baseboards, if necessary, with approved pesticides.

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NATIONAL PARK SERVICE
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DUTCH ELM DISEASE

Final Report

30 September 1984

Submitted To:

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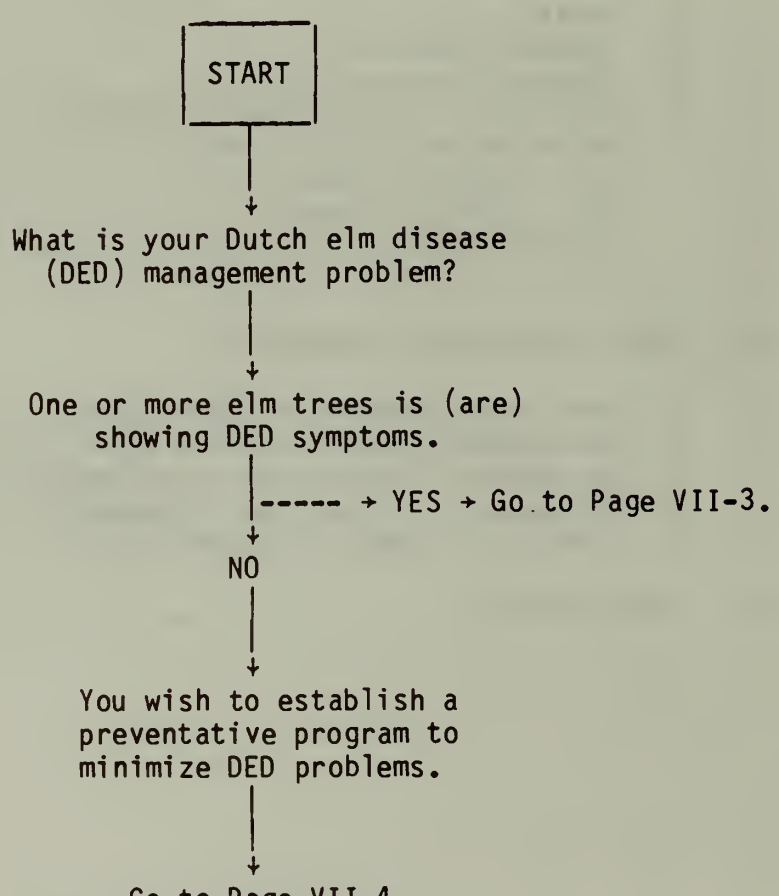
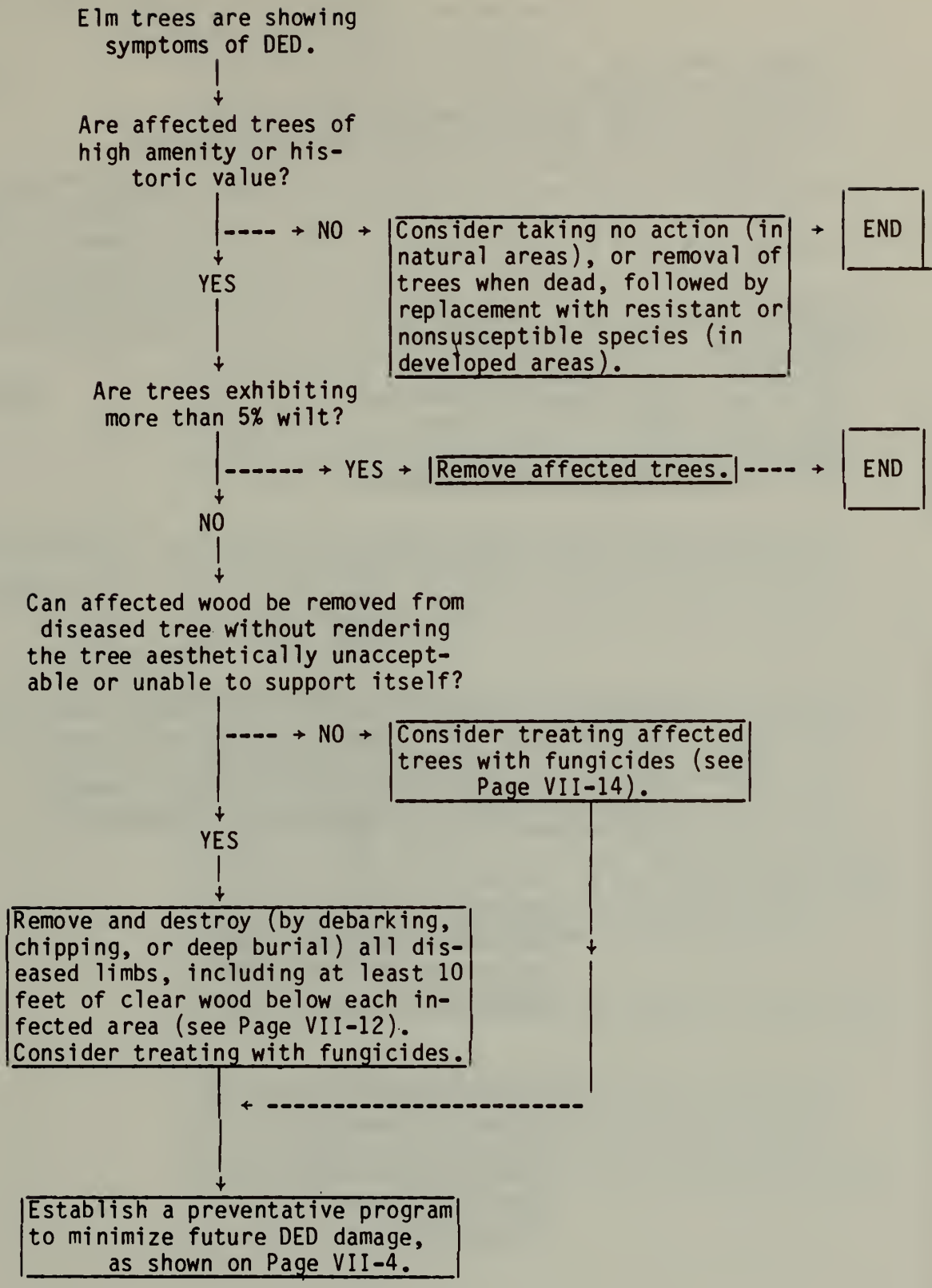
CONTENTS

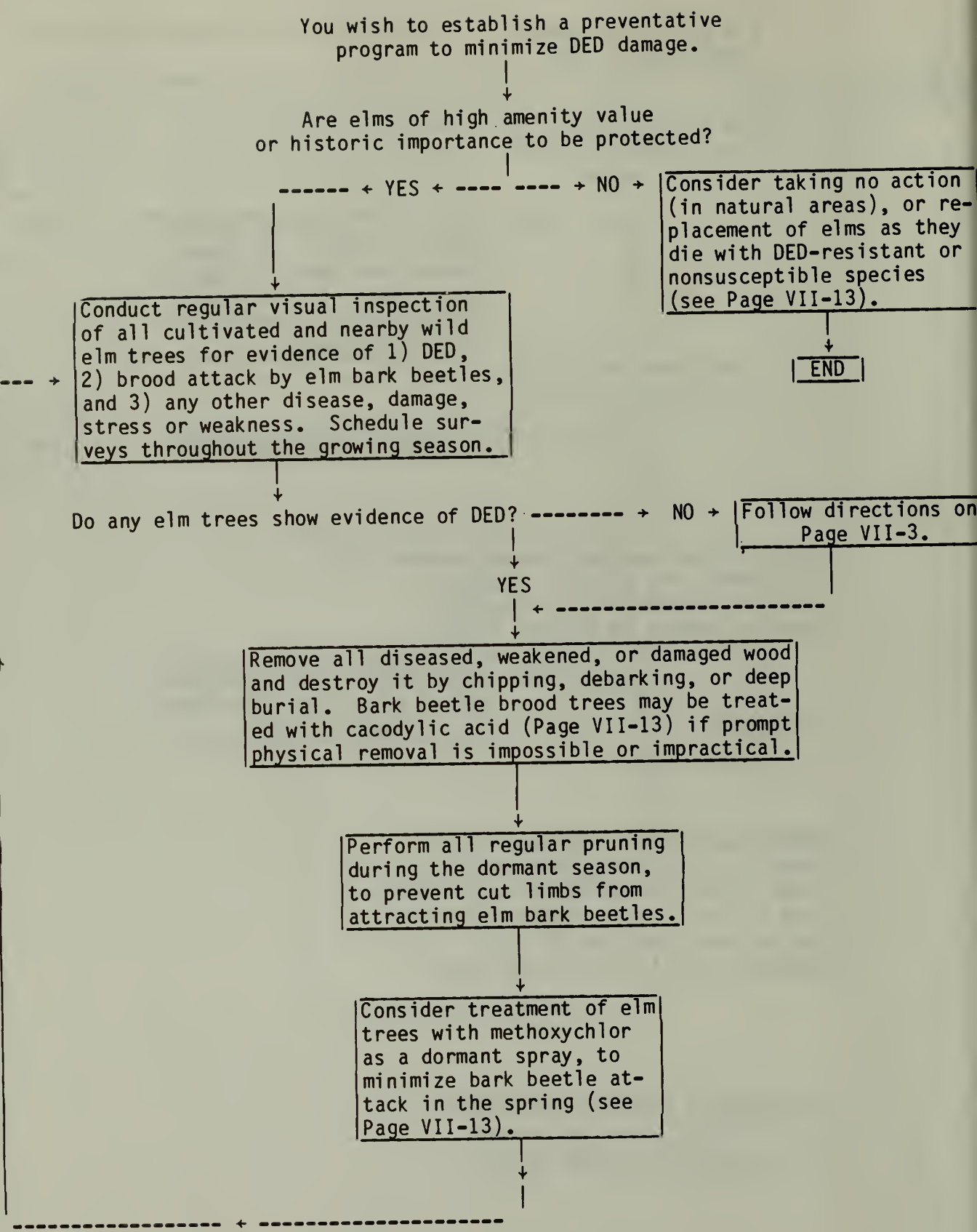
Section		Page
I.	DUTCH ELM DISEASE IPM DECISION TREE	VII-2
II.	DUTCH ELM DISEASE BIOLOGY AND ECOLOGY	
	1. Disease Described	VII-5
	2. Geographic Distribution	VII-5
	3. Habitat	VII-5
	4. Hosts	VII-5
	5. Disease Cycle	VII-6
	6. Seasonal Abundance	VII-8
	7. Responses to Environmental Factors	VII-9
	8. Impact of Dutch Elm Disease	VII-9
	8.1. Direct Impact	VII-9
	8.2. Indirect Impact	VII-9
	9. Natural Enemies	VII-10
III.	DUTCH ELM DISEASE MANAGEMENT	
	1. Population Monitoring Techniques	VII-11
	2. Threshold/Action Population Level	VII-11
	3. Management Alternatives - Nonchemical	VII-11
	4. Management Alternatives - Chemical	VII-13
	5. Summary of Control Recommendations	VII-14
IV.	BIBLIOGRAPHY	VII-16

I. DUTCH ELM DISEASE IPM DICISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


START
What is your Dutch elm disease (DED) management problem?
One or more elm trees is (are) showing DED symptoms.
----- → YES → Go to Page VII-3.
NO
You wish to establish a preventative program to minimize DED problems.
Go to Page VII-4.


Elm trees are showing symptoms of DED.
Are affected trees of high amenity or historic value?
NO
Consider taking no action (in natural areas), or removal of trees when dead, followed by replacement with resistant or nonsusceptible species (in developed areas).
END
YES
Are trees exhibiting more than 5% wilt?
YES
Remove affected trees.
END
NO
Can affected wood be removed from diseased tree without rendering the tree aesthetically unacceptable or unable to support itself?
NO
Consider treating affected trees with fungicides (see Page VII-14).
YES
Remove and destroy (by debarking, chipping, or deep burial) all diseased limbs, including at least 10 feet of clear wood below each infected area (see Page VII-12). Consider treating with fungicides.
Establish a preventative program to minimize future DED damage, as shown on Page VII-4.


You wish to establish a preventative program to minimize DED damage.
Are elms of high amenity value or historic importance to be protected?
YES
NO
Consider taking no action (in natural areas), or replacement of elms as they die with DED-resistant or nonsusceptible species (see Page VII-13).
END
Conduct regular visual inspection of all cultivated and nearby wild elm trees for evidence of 1) DED, 2) brood attack by elm bark beetles, and 3) any other disease, damage, stress or weakness. Schedule surveys throughout the growing season.
Do any elm trees show evidence of DED?
NO
Follow directions on Page VII-3.
YES
Remove all diseased, weakened, or damaged wood and destroy it by chipping, debarking, or deep burial. Bark beetle brood trees may be treated with cacodylic acid (Page VII-13) if prompt physical removal is impossible or impractical.
Perform all regular pruning during the dormant season, to prevent cut limbs from attracting elm bark beetles.
Consider treatment of elm trees with methoxychlor as a dormant spray, to minimize bark beetle attack in the spring (see Page VII-13).

DUTCH ELM DISEASE BIOLOGY AND ECOLOGY

Disease Described:

Dutch elm disease is caused by the fungus *Ceratocystis ulmi*. For a complete description of the pathogen, see Agrios (1969) or Stipes and Campana (1981). The first symptoms of DED are sudden or prolonged wilting of the leaves of individual branches (occasionally of an entire tree). Wilted leaves may curl, turn yellow, then brown, and finally fall or remain attached to their branches. DED usually appears initially on one or more branches, and spreads to other portions of the tree. Affected trees may die branch by branch over a period of years, or may develop symptoms over the entire tree and die within a single growing season. Trees infected in the spring or early summer are likely to die quickly; those infected later in the growing season are usually less severely affected, but may die during the following year.

If the bark is peeled back from infected twigs or branches, brown streaking or mottling is visible in the outer layers of wood. In cross section, the discoloration appears as a broken or full ring in the outer growth rings.

Geographic Distribution:

C. ulmi is an exotic pest which may have originated in Asia. The first known cases of DED in the U.S. were found in Cleveland and Cincinnati, Ohio, in 1930; the fungus had apparently been brought into the U.S. in elm wood imported from Europe. Since then, the disease has spread throughout the U.S., except for the states of Florida, Louisiana, Arizona, New Mexico, Utah and Nevada. A new, more aggressive strain of the fungus appeared in Canada in the 1960's, and has spread throughout the eastern U.S. during the 1970's.

Habitat:

C. ulmi can exist throughout the range of susceptible host trees.

Hosts:

All species of elms (genus *Ulmus*) are attacked by DED. The American elm, which is the most valuable native species, is one of the most susceptible. Certain elm species appear to have limited resistance to *C. ulmi* (see Page VII-12).

5. Disease Cycle:

A. Overwintering - C. ulmi overwinters in the bark of dying or dead infected trees and logs as mycelium or spore-bearing structures (coremia).

B. Spread to Healthy Trees

1. Root Grafts - C. ulmi can move directly from disease to healthy trees through natural root grafts that commonly form between adjacent trees, especially those growing less than 50 feet apart. The fungus is carried (as spores) or grows (as mycelium) direct from the vascular tissues of the infected tree to those of the healthy tree through their connection at the graft.

2. Vectors - The vectors of C. ulmi are species of elm bark beetles (Scolytidae), since they visit and create wounds in the sapwood of healthy elm trees. The Scolytids which vector C. ulmi in the U.S. are the European elm bark beetle, Scolytus multistriatus and the American elm bark beetle, Hylurgopinus rufip For a description of these species see Agrios (1969) or Stipes and Campama (1981). The European elm bark beetle was introduced into North America before the 20th century, along with S. mali, which prefers to breed in apple and cherry trees, so is of only secon dary importance (Stipes and Campana, 1981). S. multistriatus has replaced H. rufipes as the major vect of C. ulmi in areas of the U.S. where winter temperatures do not fall to -6°F (which kills overwinte ing larvae of S. multistriatus). H. rufipes is still an important vector in Minnesota, Wisconsin, Maine, Northern New York and New England, and most of Canada.

Damaged or weakened elm wood releases attractants which lure adult elm bark beetles. The beetles tunnel into the inner bark to breed. Virgin female European elm bark beetles produce two additional aggregating pheromones which attract large numbers of males and females to the tree; American elm bark beetles are not known to produce these pheromones. Millions of beetles may attack a single elm. Each female beetle tunnels between the bark and sapwood of the brood tree, laying a row of eggs on each side of her "maternal gallery". Up to 100 eggs may be produced by a single female. The direction of the maternal gallery is species specific: those of S. multistriatus run parallel to the grain of the wood, while those of H. rufipes are oriented at a 45° angle to the grain.

Larvae hatch from the eggs in about a week; the white, legless grubs tunnel perpendicularly to the direction of the maternal gallery, feeding on elm phloem cells for 4-5 weeks. Pupation lasts about 1-2 weeks, after which the red-brown, 1/8" adult beetles emerge from the trees through small holes. New adults become contaminated with C. ulmi spores as they tunnel through the brood tree toward the surface. The fungus grows throughout the insects' tunnels, producing coremia with their sticky spores; as the beetles pass through the tunnels, thousands of spores adhere to their bodies.

After emergence from the brood tree, adult beetles fly to healthy elms to feed, or to declining elms to breed. Adult beetles may fly up to 400-600 yards from their emergence tree before attacking a brood tree. If picked up by air currents, adult beetles may be carried 20-50 miles (G.N. Lanier, personal communication) before landing to breed.

- Scolytus beetles often feed on or tunnel into twig crotches in the crowns of healthy elms; healthy twigs 1-1 1/2 years old seem to be preferred (Stipes and Campana, 1981). In early summer, most feeding occurs at the junction of a current shoot and the previous year's growth; late season injury is often on new shoots at the bases of leaf petioles. H. rufipes feeds on larger branches, up to about 4 inches in size. During the feeding period, fungal spores may be introduced into the new host trees.

Bark beetles frequently feed on logs cut for lumber and fuel. Such colonized wood may become reservoirs for C. ulmi, even if the wood is of a resistant species (e.g., Siberian elm).

- Breeding attacks frequently occur on elm trees with recently broken, stressed, or pruned limbs. Such trees often become infected by C. ulmi whether or not the beetles successfully establish broods.

S. multistriatus commonly produces two generations per year; the first overwinters as larvae, pupates in early spring, and emerges as elms reach full leaf. The second generation flies in late summer, producing the broods that overwinter. H. rufipes usually overwinters as adults in the bark at the bases of healthy elms, and may cause C. ulmi infections during fall feeding in lower boles, or during spring feeding in branches. H. rufipes may produce

one or one and one-half generations per year (overwintering as larvae or adults in alternate years), depending on the duration of warm weather (Stipes and Campana, 1981).

C. Development Within The Host - When spore-laden bark beetles tunnel through the bark and wood of elm stems, C. ulmi spores are deposited into wounded tree tissues, germinate rapidly, and grow into the bark and wood. When the fungus reaches the large xylem vessels of spring wood, it produces single-celled spores which are carried up the sap stream. These spores reproduce by budding, to begin new infections. Symptom development follows the vascula invasion front. Initially, only the xylem vessels and associated cells are affected. Eventually, the mycelium invades nonvascular tissues, growing intercellularly through the parenchyma.

D. Reaction Of The Host - Infected elm trees react to t presence of C. ulmi with a series of responses. Sticky gums are produced in affected cells, which block up some vessels. Outgrowths of vessel parenchyma cells (tyloses) grow into vessels through pits and block the vascular system. Walls of affected cells become brown, due to toxins secreted by the fungus and to enzymatic activity of the injured cell

Infected twigs and branches wilt and die rapidly, du to a mechanism which is not understood, although blockage of the vascular system no doubt contributes to the wilt.

Spring or early summer infections result in invasion of the large springwood vessels, allowing rapid transport of fungal spores throughout the tree. If the vascular infection becomes general, the tree may die in a few weeks. Later infections are usually limited to the narrower summerwood vessels, resultin in slower fungal movement, and localized damage which may not become serious until the following season.

6. Seasonal Abundance:

A. Vectors - Elm bark beetles usually overwinter as larvae, but the American bark beetle also may overwinter as adults. In Syracuse, New York, population of adult S. multistriatus were observed to peak in June, August (the largest peak), and September (the smallest) (Stripes and Campana, 1981). H. rupifes adult populations peaked in April (emerging overwintering adults), July-August, the following

June-July, and from August to frost of the second year. In Washington, D.C., S. multistriatus overwinters as larvae, emerging in May-June to produce a second generation which emerges in July-August (and, in mild weather conditions, a smaller emergence in the fall)(Sherald, 1982).

B. Pathogen - C. ulmi grows and sporulates in elm tissues throughout the growing season. Spread from tree to tree through root grafts does not require vectors, so can occur any time that temperatures are high enough to permit fungal growth. Host trees are most susceptible to infection in late spring and early summer, when large springwood xylem vessels have been produced.

Responses to Environmental Factors:

The sporulation of C. ulmi is temperature-related. Asexual spores are most commonly produced during the warm months; coremia are most frequent from July through October. When sexual reproduction occurs (it is rare in nature), the production of fruiting bodies (perithecia) increases with falling temperature, and is most common between November and February.

Impact of Dutch Elm Disease:

8.1 Direct Impact:

Prior to the introduction of DED into the U.S. in 1930, the American Elm (U. americana L.) was one of the most popular street trees throughout the Northeast, Middle Atlantic, and Midwest regions; approximately 77 million elms were growing in incorporated areas in the U.S. By 1976, about 43 million of those trees had been lost to DED (USFS, 1977). An additional impact of DED is the loss of shade and aesthetic beauty in formerly elm-planted urban areas. The impressive shape, size, fall color, and shade quality of the American elm led to the institution of a near monoculture of this species in urban areas, which has served to enhance the spread of DED.

8.2 Indirect Impact:

The major indirect impact of DED is the cost of removal and replacement of elm trees which have been killed. Sherald (1982) reported that the estimated costs of these procedures may be as much as $100 million annually in the U.S.

9. Natural Enemies:

A. Pathogen - Strobel and Lanier (1981) reported moderate success in controlling DED in small scale tests by injecting trees with the bacterium Pseudomonas syringae van Hall, a plant pathogen that inhibits C. ulmi in vitro. O'Brien et al. (1984) attempted to obtain control by injecting trees with isolates of Streptomyces spp. which were inhibitory to the fungus in vitro; no prevention of DED was found.

B. Vectors - The following predators and parasites are known to attack S. multistriatus in the U.S. and Canada: the wasps Dendrosoter protuberans (introduced), Spathius canadensis, Entodon leucogramma and Cheiropacus colon; the flies Lonchaea polita and L. ciliata, and the mite Pymotes scolyti (Pfadt,1978; Save the Elms Task Force, 1983). None of these organisms is known to provide effective levels of biological control of this beetle. Although H. rufipes is a native beetle, no naturally-occurring agents are known which can provide useful levels of control of this beetle.

III. DUTCH ELM DISEASE MANAGEMENT

1. Population Monitoring Techniques:

C. ulmi does not produce wind-or water-borne spores, and only develops mycelium inside infected trees or logs. Therefore, direct monitoring techniques for the fungus would not be useful. The best monitoring technique is visual observation of trees for DED symptoms (wilt of isolated branches or a general wilt accompanied by vascular discoloration). Since these symptoms are produced by other wilt diseases as well (Stripes and Campana, 1981), it may be useful to collect samples of infected material for analysis by an extension or state university plant pathologist.

The use of sticky traps to monitor populations of elm bark beetles is currently under investigation (Lanier, 1983 and personal communication).

2. Threshold/ Action Population Levels:

Due to the aesthetic importance of the American elm in urban settings, the widespread distribution of *C. ulmi* and its insect vectors, and the likelihood of root-graft transmission throughout an elm grove or row once any member tree becomes infected, the presence of *any* diseased branches or limbs indicates that management procedures must be initiated.

3. Management Alternatives - Nonchemical:

A. Sanitation - The single most effective way to prevent or minimize new infections of *C. ulmi* is sanitation. The goals of sanitation are:

1. The eradication of known sources of disease, by destroying all diseased trees and tree parts; and

2. Reduction of the inoculum potential of *C. ulmi* by making all wood which could support fungal growth and sporulation unusable by the pathogen; and

3. Reduction of the vector potential of bark bettles by destroying all elm wood attractive to beetle attack, including elm branches or stems weakened, dying, or dead from *any* cause.

An effective sanitation program must include the following:

1. Making regular visual surveys for DED symptoms throughout the growing season, beginning when elms leaf out in the spring, and continuing until dormancy in the fall.

2. Rapidly removing and destroying all diseased trees, and pruning diseased limbs; at least 10 feet of nondiscolored wood must be removed below the point of symptom expression, to ensure that tissues harboring fungal spores and mycelium are removed from the tree. Pruning may be combined with fungicidal injection (see Page 13). Pruning should be performed immediately (tree removal within 20 days) after disease detection (Sherald, 1982). Root grafts (see below) must be destroyed before a diseased tree is removed, to prevent diseased sap from flowing into adjacent healthy trees after the trunk of the diseased tree is cut.

3. Destroying all wood removed by chipping, deep burying, burning, or debarking; this renders the wood unfit for colonization by bark beetles.

4. Performing regular pruning of elm trees only during the dormant season (October to February), so that pruning cuts will not attract bark beetles.

5. Sterilization of all pruning tools before each cut by dipping in denatured alcohol or chlorine bleach, to prevent infection of healthy wood by spores contaminating tool surfaces.

B. Root Graft Interruption - When diseased elm trees are found within 50 feet of healthy elm trees, root grafts between the diseased tree and surrounding trees must be destroyed or prevented. A trench 36-40 inches deep (the width of the trench is not critical) between trees will sever nearly all root grafts, since most large elm roots are found within 2 feet of the soil surface. The trench can be backfilled immediately after it is dug. Trenching between the first and second closest healthy trees will add an extra degree of safety, in case the closest tree has already been infected.

C. Irrigation - In arid areas (especially in the Western U.S.), the provision of sufficient water for proper elm growth may reduce drought stress, which can promote bark beetle attack, resulting in DED.

D. Resistance - Although all elm species are attacked by C. ulmi, not all are as severely affected as is the American elm. Among those species in which

resistance has been found are the Smooth-leafed elm (U. carpinifolia cvs.), Dutch elm (U. x hollandica), Chinese elm (U. parvifolia), Siberian elm (U. pumila), Himalayan small-leafed elm (U. villosa), and hybrids of these species (such as the urban elm [(U. x hollandica 'Vegeta' x U. carpinifolia) x U. pumila] and Sapporo Autumn Gold elm [U. pumila x U. japonica]). Hybridizing any of these with the American elm is difficult (because the American elm is tetraploid). Most resistant species do not have the distinctive shape and/or the cold hardiness of the American elm. None of the resistant species is completely resistant to all strains of the fungus, so any could be destroyed in the future by different races of C. ulmi.

E. Replacement with Other Species - The extreme reliance of urban planners on the American elm created the monoculture that permitted the rapid spread of DED throughout the U.S. Replacement of destroyed elms with other large shade trees will dilute this monoculture, reducing the rate of spread of DED among remaining elms. The more diverse urban plantings become, the smaller are the risks of extensive loss due to single factors such as DED.

Japanese zelkova (Zelkova serrata) has been suggested as a replacement for elms, because its size and shape are similar to those of American elm and because it is less susceptible to DED than is the American elm. Weeping linden (Tilia petiolaris) has an effective shape and is not affected by C. ulmi.

Management Alternatives - Chemical:

A. Cacodylic Acid - Destruction of an elm bark beetle-infested tree can be performed before cutting by applying cacodylic acid in cuts around the trunk, or by injection into root flares. Treatment should be performed while the tree is in leaf to enhance translocation. Cacodylic acid causes rapid drying of the wood, and destroys beetle eggs and larvae. This technique can be used in natural areas or other locations where tree removal must be delayed or is impractical.

B. Insecticides - Application of insecticides to all bark surfaces of dormant elm trees can prevent C. ulmi infection by preventing beetle feeding. Methoxychlor is routinely used for mist blower (at 12.5% active ingredient) or hydraulic sprayer (2% AI) application. Follow all label directions.

C. Fungicides - Since C. ulmi grows inside the tree, normal foliar fungicide application is not effective against it. Injection of fungicides such as Arbotect 20-S and Lignasan-BLP directly into affected limbs and trunks may be effective in controlling DED. However, injection produces wounds which may become infected by various organisms. Fungicides can aid pruning therapy, if the treatment is applied to the affected limb(s) and trunk 2-10 days prior to removal of the limb(s) (Sherald, 1982). Contact your Regional or WASO IPM Coordinator for more information.

D. Root-Graft Destruction - Grafts may be destroyed by application of the soil-fumigant Vapam (SMDC) to holes drilled into the soil between trees. See Sherald (1982) for a discussion of recommended metho Follow all label directions.

E. Elm Bark Beetle Trapping - The bark beetle attractan produced by stressed elm wood and by female European bark beetles have been synthesized. Lanier (1978) has studied the effectiveness of these attractants as baits to lure beetles to sticky cardboard traps. He reported that the use of such baited traps on utility poles and nontarget trees may be effective in reducing DED in elm groves. Testing of beetle trapping for protection of high-value elms is currently underway in the Washington, D.C. area (Lanier, 1982; Lanier, 1983). Sticky traps and attr ant formulations are available from DeWill, Incorporated, Riverside, Illinois (DeWill Elm Bark Beetle Trap and Entrap Insect Lure, respectively). Contact your regional IPM Coordinator for further informatio

5. Summary of Management Recommendations:

A. Where American elm trees must be maintained because of historic significance or overriding aesthetic concern, the following procedures are recommended to minimize DED damage and the possibility of new infection:

1. Regular surveys for DED symptoms on cultivated and nearby wild elm trees throughout the growing season (from leafing out to dormancy);

2. Rapid removal of diseased tree parts or trees, and destruction of removed wood;

3. Chemical sanitation with cacodylic acid where removal would be delayed beyond 20 working days after discovery of disease symptoms;

4. Destruction of brood wood of elm bark beetles;

5. Destruction of root grafts around diseased elm trees and their nearest healthy neighbors;

6. Pruning of all weakened, broken, or dying elm branches and destruction of the wood;

7. Delaying of normal pruning until dormancy;

8. Treatment of dormant trees during late winter/early spring with methoxychlor, to prevent insect colonization (this may not be needed if thorough sanitation is performed on all elm trees, including wild trees);

9. Trapping of elm bark beetles using Multilure-baited adhesive traps; and

10. Replacement of destroyed elms with resistant varieties or nonsusceptible tree species.

Treatment with fungicides may be necessary in certain cases. Contact your regional NPS IPM Coordinator for approved procedures.

B. In Other Areas - Since DED is extremely widespread, and therapy of diseased trees is often expensive, it may be practical to remove elm trees as they are killed, and replace them with other large-growing shade trees. In natural areas, treatment of diseased elm trees would be difficult, and dead elms would most likely be replaced with other species immune to DED without a major impact on the forest community; therefore, we recommend no treatment for these areas.

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NATIONAL PARK SERVICE
IPM Information Package

PEST BIRDS:
PIGEONS, STARLINGS, HOUSE SPARROWS

Final Report

30 September 1984

Submitted To:

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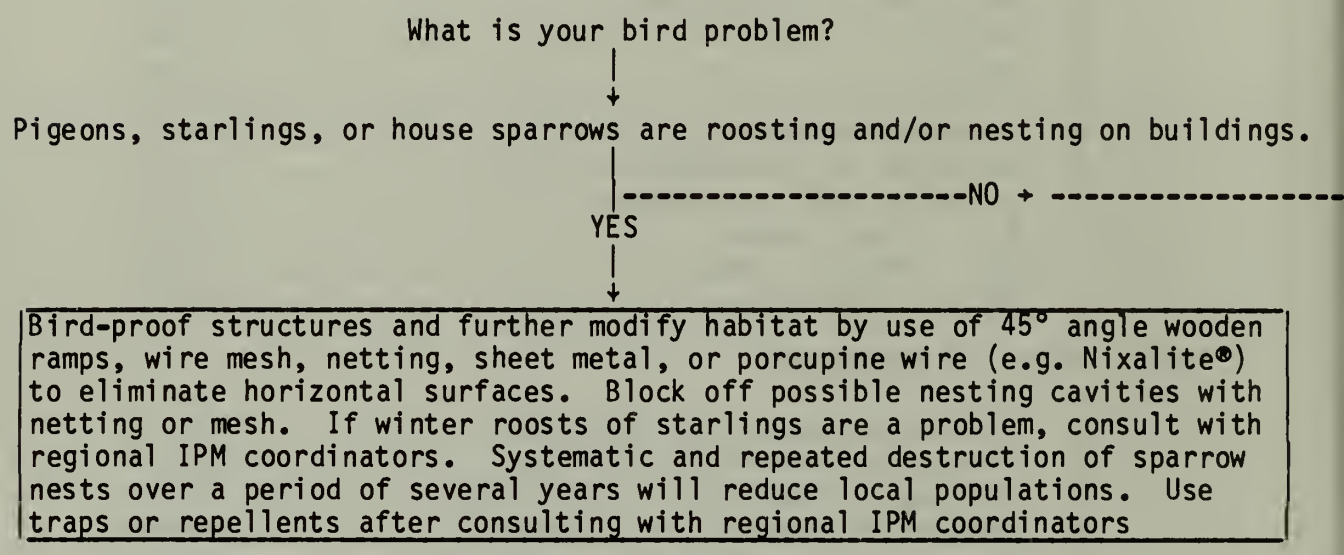
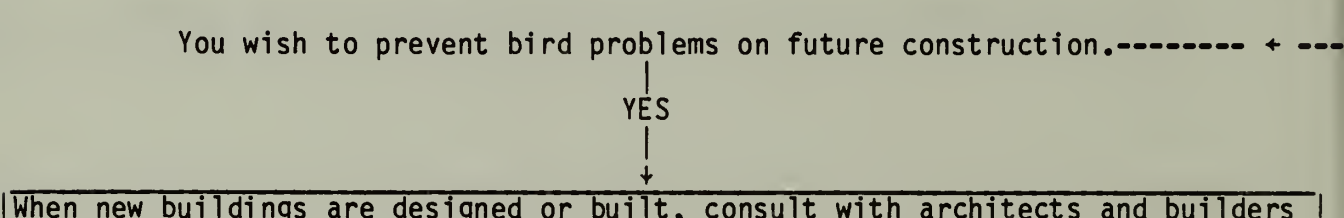
CONTENTS

Section		Page
I.	PEST BIRD IPM DECISION TREE	XXIV-2
II.	BIOLOGY AND ECOLOGY OF PEST BIRD SPECIES	
	1. Species Described	XXIV-3
	2. Geographic Distribution	XXIV-3
	3. Habitat	XXIV-3
	4. Hosts	XXIV-4
	5. Life Cycles	XXIV-4
	6. Seasonal Abundance	XXIV-5
	7. Responses to Environmental Factors	XXIV-5
	8. Impact of Pest Bird Species	XXIV-5
	8.1. Direct Impact	XXIV-5
	8.2. Indirect Impact	XXIV-6
	9. Natural Enemies	XXIV-6
III.	PEST BIRD MANAGEMENT	
	1. Population Monitoring Techniques	XXIV-7
	2. Threshold/Action Population Level	XXIV-7
	3. Management Alternatives - Nonchemical	XXIV-7
	4. Management Alternatives - Chemical	XXIV-8
	5. Summary of Management Recommendations	XXIV-9
IV.	BIBLIOGRAPHY	XXIV-10

I. PEST BIRD IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


What is your bird problem?
Pigeons, starlings, or house sparrows are roosting and/or nesting on buildings.
NO
YES
Bird-proof structures and further modify habitat by use of 45° angle wooden ramps, wire mesh, netting, sheet metal, or porcupine wire (e.g. Nixalite®) to eliminate horizontal surfaces. Block off possible nesting cavities with netting or mesh. If winter roosts of starlings are a problem, consult with regional IPM coordinators. Systematic and repeated destruction of sparrow nests over a period of several years will reduce local populations. Use traps or repellents after consulting with regional IPM coordinators


You wish to prevent bird problems on future construction.
YES
When new buildings are designed or built, consult with architects and builders to make them aware of potential problems, and to ensure that potential bird problems are not designed or built into the buildings.

II. BIOLOGY AND ECOLOGY OF PEST BIRD SPECIES

1. Species Described:

Three birds: pigeons, starlings, and house sparrows are considered common pest species and all are exotic species.

A. Feral pigeon or rock dove - (*Columba livia*)

B. Starling - (*Sturnus vulgaris*)

C. House or English sparrow - (*Passer domesticus*)

See pages 179-180, U.S. Department of Health, Education, and Welfare (1967), or any field guide to American birds for illustrations and descriptions.

2. Geographic Distribution:

A. Pigeons were introduced into North America as a food animal in the early 17th century. Feral pigeons are found throughout North America, especially in urban areas and on farms. In Eurasia, the ancestral bird (rock or blue dove) is found along coasts and in rocky areas (Marsh and Howard, 1982).

B. Starlings were introduced into New York City in the 1890's. They are now found throughout the U.S., including Alaska and Hawaii.

C. House sparrows were introduced into North America in 1850. They are now found throughout the U.S. in cities and on farms.

3. Habitat:

A. Feral pigeons nest commonly on building ledges, roofs, cliffs, or in caves.

Pigeons are attracted to cities by the availability of habitat and by abundant food sources such as spilled grains, garbage, and other foods.

Adults eat about a pound (1/2 kg.) of food each week. Pigeons eat seeds, grains, and other vegetable materials, some insects, animal manure, garbage, and grit.

B. Starlings nest in natural or man-made cavities.

Starlings often roost in cities in winter, attracted by sources of warmth such as heat

vents. They feed away from their roosting sites. They sometimes flock in numbers that disrupt surrounding areas.

Adult starlings are insectivorous to omnivorous, feeding on insects, fruit, and grains.

C. House sparrows originally were found primarily in cities where they fed on undigested grain in horse manure. With the increased use of the auto, they have shifted their diet to include more insects, seeds, and foodstuffs discarded by humans.

House sparrows nest on any elevated semi-protected spot such as gutters, rafters, or ledges.

Adult diets consist of insects, and a variety of seeds, grains, fruits, and buds.

4. Hosts: Not applicable.

5. Life Cycles:

A. Pigeons - Breeding occurs year round but peaks in spring and summer.

Nests are crude and flimsy platforms about 1 foot in diameter constructed from sticks, grasses, and twigs. One to two white eggs are laid in each nest. One adult pair may raise several broods in a single season. Eggs are incubated by both parents, and require 17-19 days to hatch. Young birds (squabs) are fed "pigeon milk" (predigested food) from the adult crop. Young fledge in 35-37 days. Eggs of the next brood are often laid before the existing brood is weaned and fully fledged. Pigeons are monogamus and mate for life.

Pigeons commonly live for up to 15 years, and occasionally up to 30 in captivity. In the wild, mortality rates are approximately 33% per year in adults, and nearly 50% per year in juveniles. Only about 1/3 of the adults reproduce each year.

B. Starlings - Starlings mate in spring and lay 3-8 eggs per clutch.

Starlings are cavity nesters. There are 1-3

broods per year. Nests are made of fiberous materials and lined with soft material such as grass, down, or feathers. Incubation lasts for approximately 12 days. The young are fed primarily on insects by the parents. The young fledge in 2-3 weeks after hatching. After fledging, young birds form small flocks which coalesce as the season progresses to form large roosting flocks, numbering up to several thousand individuals.

C. House sparrows - The peak breeding season is spring, but broods are produced throughout the warm months (late April to October).

Nests are usually constructed near each other, and are made of twigs, grass, paper, and string. House sparrows lay 3-8 eggs per clutch. Incubation lasts 11-17 days, and the young fledge in about 2 weeks. Young are fed on insects by the adults. Mortality rates for young in their first year is over 50%.

6. Seasonal Abundance:

As with other birds, populations of pestiferous species peak in late summer when all broods have fledged and before seasonal mortality factors (shortage of available food, drinking water, and cold, wet weather) have begun to make themselves felt.

7. Response to Environmental Factors:

Cold, wet winters and springs are major causes of bird mortality, espcially when combined with lack of food and available water.

8. Impacts of Pest Bird Species:

8.1 Direct Impact:

The most obvious direct impact of pest birds is the noise and debris they produce. Bird droppings can deface statuary and masonry. Bird excrement may also kill lawns and shrubbery when it becomes too abundant, and will cause objectionable odors. Droppings and nests attract pest insects such as roaches and carpet beetles. Nests obstruct drain pipes, mar windowsills, interfere with awnings, and create hazardous footing on fire escapes. Bird droppings, feathers, and nesting materials may create fire hazards, obstruct chimneys, and often contaminate grain. Large quantities of grain may be consumed by birds that live

around grain-handling establishments (Ebeling, 1976).

Starlings and, to a lesser extent, house sparrows are believed to be largely responsible for the decline in the populations of several native species of cavity nesting birds including the eastern bluebird and red-headed woodpecker.

8.2 Indirect Impact:

Pest birds may spread diseases to humans or livestock through droppings or by droplets from respiration.

A. Pigeons - Pigeons have been demonstrated to carry pigeon ornithosis, which causes psittacosislike symptoms which are usually mild in humans. Pigeons are known carriers of encephalitis viruses; aspergillosis, a fungus disease of the human ear sinuses, lungs, or skin; and "thrush", a fungal infection of the mouth, respiratory system, urogenital tract, skin, or fingernails. Pigeon manure may harbor spores of the fungus which causes histoplasmosis; in one study, it was found that children living in buildings where pigeons nested had an infection rate 3 times that of children living in pigeon-free structures (Ebeling, 1975). Pigeons also harbor Newcastle disease, a highly contagious and fatal virus of domestic fowl, and are implicated in the transmission of hog cholera (Ebeling, 1975).

B. Starlings - A high incidence of positive tests for histoplasmosis has been found in persons living near starling roosts (Marsh and Howard, 1982).

C. House sparrows - Due to the close association of house sparrows with human activities and the high rate of encephalitis antibodies found in house sparrows (an indication of long-term infection), this species is believed to be among the most important bird reservoirs for this disease (Ebeling, 1975).

9. Natural Enemies:

As with all birds, pest species are attacked by a variety of predators, parasites, and pathogens.

III. PEST BIRD MANAGEMENT

1. Population Monitoring Techniques:

Pest birds are monitored by visual inspection of numbers of individuals and of nesting and roosting areas.

2. Threshold/ Action Population Levels:

The determination of tolerable numbers of pest birds is difficult. The public, in general, interacts positively with birds (watching and feeding), especially in urban areas. Conversely, the public is annoyed by the nuisance caused by bird sounds in roosts, debris, and droppings. Park managers must determine what population levels are tolerable in their parks.

3. Management Alternatives - Nonchemical:

1. Pigeons - Sanitation, i.e., removal of food sources will greatly reduce the attractiveness of an area to pigeons. All spilled food or refuse should be removed on a regular basis. Persons who regularly feed pigeons in urban areas should be approached and dissuaded from feeding, or asked to cut back on the amount of food fed. Sanitation programs aimed at rats will also reduce the amount of food available for birds. Nest and nest site removal should also be included in a sanitation program. Nest removal may be particularly useful in sparrow control programs, but must be combined with other measures such as bird proofing to have long term effects.

Buildings should be bird-proofed to prevent roosting and nesting by pigeons and sparrows. Openings in buildings, and horizontal roosting and nesting surfaces should be screened off with 1/2 inch-mesh rust proof wire or commercial bird netting. Ledges should be fitted with wooden ramps, sheet metal, or plexiglass forming a 45° angle to prevent roosting or nesting. Ledges and window sills should be fitted with porcupine wire such as Nixalite® to prevent roosting. Porcupine wires should be inspected periodically to remove any accumulatin of debris which may provide suitable roosting and nesting surfaces. Cables, such as those used in roof supports, should be fitted with 25 gauge (.059 inch diameter) music wire 3 inches above the cable, and held in place by brackets and clamps to prevent roosting (Manski, 1982). In cases where historic buildings are involved, the

historic integrity of structures should be preserved; consult with the regional historian before structural modifications are undertaken.

Frightening devices are ineffective for pigeons, which rapidly habituate to devices such as plastic owls and snakes. Changing positions of devices may serve to lengthen the habituation period. Auditory repellants, such as fire crackers or recorded alarm calls, are also habituated to in a short time.

Trapping has been used with success in reducing or removing pigeons, especially when numbers are small. See Marsh and Howard (1982) for details on types of live traps available. Any native birds or privately owned banded pigeons which have been trapped should be released. The rest should be disposed of in a humane manner.

Before any trapping program is begun, check with your regional IPM Coordinator to determine regulations and permits required.

2. Starlings - The same management methods used for pigeons are effective for starlings. Openings in buildings should be sealed where appropriate. When large flocks of starlings are roosting in trees, selective pruning to open the canopy and to make tree cover unsuitable for roosting is often effective.

3. House sparrows - Management methods for pigeons are also effective for house sparrows. Nest destruction may be useful in population reduction due to the relativly high yearly mortalities in sparrow populations (over 50%). Nest destruction must continue for 2 or more years before any effect is seen, and without habitat modification (screening, exclusion, etc.), the area will be recolonized from other, nearby populations in a short time.

4. Management Alternatives - Chemical:

Chemicals used in bird control may be divided into 3 groups: repellents, chemosterilants, and lethal agents. The later 2 groups are not recommended for use in NPS areas.

Repellents - Sticky repellents cause birds to avoid roosting in areas where they have been used. Although effective, tackiness is lost

in time due to dust accumulation. Sticky repellents are commercially available in gel form in cartridges, squeeze tubes, and aerosol cans.

Chemosterilants - In theory, chemosterilants reduce local populations by inhibiting reproduction and allowing mortality factors to act upon and reduce flock size. Chemosterilants in bait, when fed upon repeatedly, inhibit female fertility. To be fully effective, chemosterilants must by used on an area-wide basis due to immigration of non-sterile adult females from adjacent areas.

Lethal agents - A chemical frightening agent, 4-aminopyridin, is used at feeding sites to frighten birds away from these areas. It is available in a bait formulation, but is increasingly opposed on humane grounds. Frightening agents are lethal to birds which have consumed quantities of bait, but are slow acting. Prior to death, the affected birds display erratic behavior and emit distress cries which frighten other members of the flock into leaving the area. Generally, frightening agents are not effective on sparrows or pigeons due to less well developed communications systems of these species. See Marsh and Howard (1982) for details.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Prior to design or building of structures, consult with architects and builders to aviod designing or building suitable habitat in the structure.

2. Birdproof structures to prevent nesting and roosting. Birdproofing devices can be fabricated to blend in with the structure.

3. Clean up spilled grains or other potential foods; use good sanitation practices.

4. If necessary, trap or use chemosterilants or registered avicides to reduce populations in conjunction with the above measures. (Birdproofing will keep the area free from colonizing birds from other areas).

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NATIONAL PARK SERVICE
IPM Information Package

SILVERFISH

Final Report

30 September 1984

Submitted To:

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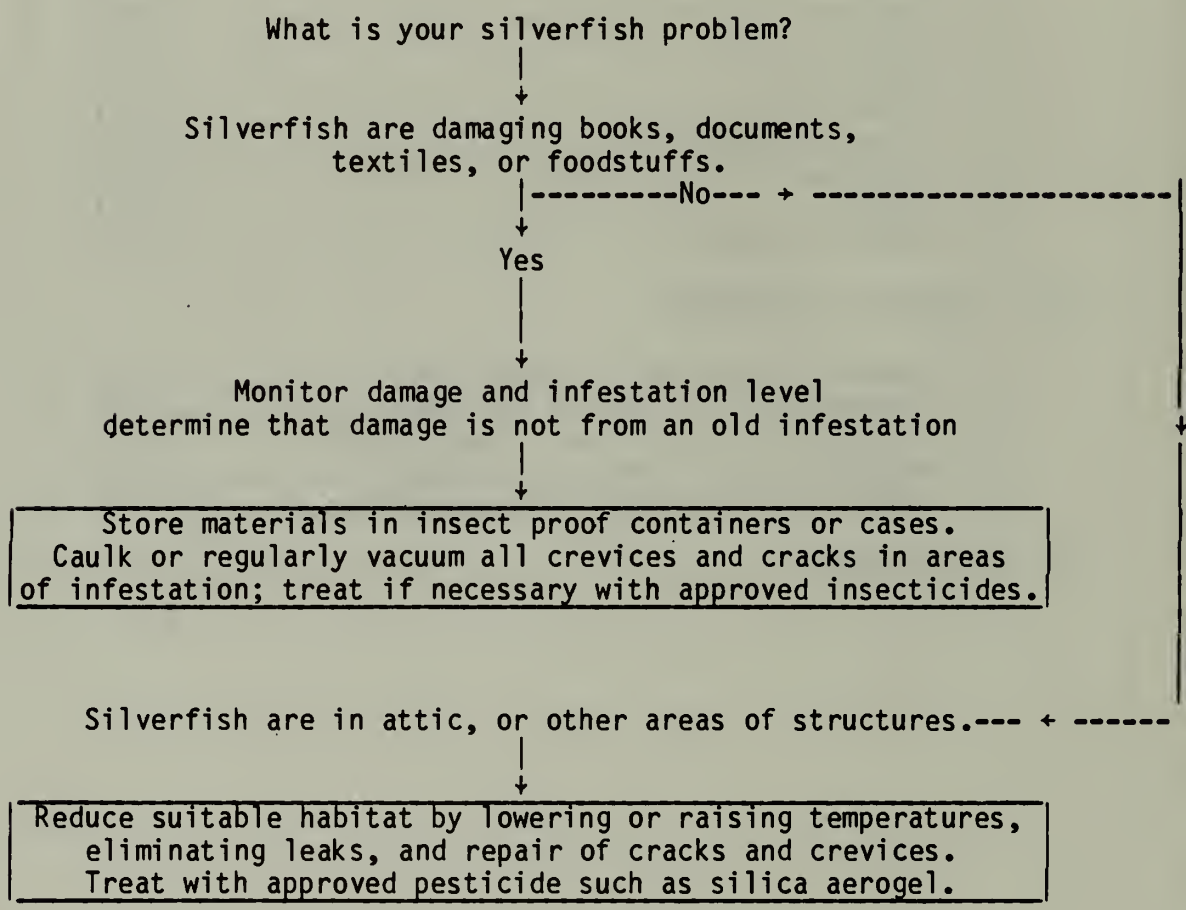
CONTENTS

Section		Page
I.	SILVERFISH IPM DECISION TREE	XXIX - 2
II.	BIOLOGY AND ECOLOGY OF SILVERFISH	
	1. Species Described	XXIX - 3
	2. Geographic Distribution	XXIX - 3
	3. Habitat	XXIX - 4
	4. Hosts	XXIX - 4
	5. Life Cycle	XXIX - 4
	6. Seasonal Abundance	XXIX - 5
	7. Responses to Environmental Factors	XXIX - 6
	8. Impact	XXIX - 6
	9. Natural Enemies	XXIX - 6
III.	SILVERFISH MANAGEMENT	
	1. Population Monitoring Techniques	XXIX - 7
	2. Threshold/Action Population Level	XXIX - 7
	3. Management Alternatives - Nonchemical	XXIX - 7
	4. Management Alternatives - Chemical	XXIX - 8
	5. Summary of Management Recommendations	XXIX - 9
IV.	BIBLIOGRAPHY	XXIX - 10

I. SILVERFISH IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


What is your silverfish problem?
Silverfish are damaging books, documents, textiles, or foodstuffs.
No
Yes
Monitor damage and infestation level
determine that damage is not from an old infestation
Store materials in insect proof containers or cases. Caulk or regularly vacuum all crevices and cracks in areas of infestation; treat if necessary with approved insecticides.
Silverfish are in attic, or other areas of structures.
Reduce suitable habitat by lowering or raising temperatures, eliminating leaks, and repair of cracks and crevices. Treat with approved pesticide such as silica aerogel.

BIOLOGY AND ECOLOGY OF SILVERFISH

Species Described:

The term silverfish is used for the order Thysanura and for any of the species within the order.

Thysanurans have a distinct carrot shaped body, short legs, long slender antennae and three tail-like appendages (anal cerci) at the end of the body. Silverfish are wingless with sacle covered bodies which are about 1/2 inch long. Nymphs resemble adults.

There are 13 species of silverfish (Thysanura) in the U.S. Mallis (1982) lists 6 species which may be pestiferous:

A. Firebrat - Thermobia domestica (Packard)

B. (no common name) - T. campbelli (Barhart)

C. Silverfish - Lepisma sacchrina L.

D. Fourlined silverfish - Ctenolepisma quadriseriata (Luccas)

E. Gray silverfish - C. longicaudata Escherich (C. urbana in some texts) (Giant silverfish)

F. (No common name) - Acrotelsa collaris (Fab.)

See page 45 of U.S. Department of Health, Education, and Welfare (1967) for pictorial keys to common species. See also Mallis and Caur (1982) for detailed descriptions of pest species.

Geographic Distribution:

A. Firebrat - Worldwide in warm climates. Found in U.S. indoors, occasionally outdoors in West and Southwest.

B. T. campbelli - Found indoors in Ohio and Pennsylvania

C. Silverfish - Common indoors on East Coast, also found indoors in Midwest and Pacific Coast.

D. Fourlined silverfish - Common on East and West Coasts and in Midwest. Lives indoors, and occasionally outdoors

E. Gray silverfish - South, Midwest, and southern California (indoors only).

F. A. collaris - Recently introduced into Florida, probably from New or Old World tropics.

3. Habitat:

A. Firebrat - Prefers heated buildings. Commonly found around ovens, bakeries, and other warm areas. (Prefers temperatures above 90°F.)

B. T. campbelli - Found indoors in libraries. Little is known about its habits.

C. Silverfish - Indoors. Found in warm, humid areas, especially basements.

D. Fourlined silverfish - Often infests attics, particularly if roof is of wooden shingles. May be found outdoors in summer.

E. Gray silverfish - Indoors only. May prefer drier areas than common silverfish such as crawl spaces and attics. May occur around water pipes in bathrooms.

F. A. collaris - Found in Florida. Little is known abo its habits.

4. Hosts:

Feeding habits of silverfish species are very simila Once a source of food is located, silverfish remain in the vicinity.

Silverfish feed on human foods, especially those containing starch or flour, as well as on paper, especially glaze-coated paper. They eat sizing on paper, as well as glue and paste. They may feed on wallpaper or the paste behind it causing it to become detached from the wall.

Materials such as writing paper, tissue, onion skin paper, and cellophane are preferred as well as cotton, rayon, and other vegetable textiles. Newsprint, brown wrapping paper, and most cardboards are seldom eaten. Silverfish feed on bound volumes for the paper, the starch and sizing in the bindings and linen bookcovers. Stored papers, books, etc. are especially susceptible. Sizing and glue are main attractants, especially if humidity is high. Wool and other animal based textiles are seldom fed upon. Cereals may become infested due to the insects' preference for starches and flour. Cellulo in paper or other wood products is broken down by enzymes and cellulose-digesting bacteria in the gut. Silverfish can live for nearly a year without feeding.

Firebrats may become serious pests in bakeries and in areas where starches are stored in warm temperatures such as warehouses.

Life Cycles:

A. Firebrat - Females deposit eggs in crevices. The number of eggs per batch ranges from 1 to nearly 200, averaging 50. Each batch of eggs is separately fertilized. Stressed females lay fewer eggs. Eggs hatch in 12-13 days under optimum conditions. Newly hatched nymphs are 2 mm long, white and scaleless. Development is rapid, with only 1 day spent in the first instar and more time passing between successive instars. A firebrat may pass through 45 to 60 instars during its lifetime. Later instars may last up to 2 weeks. Nymphs resemble adults. Females produce one batch of eggs per instar beginning at about the 12th week but can begin to oviposit at 6 weeks of age at temperatures of 90-106°F (32-40°C). Fertilization is external. Injured appendages are regenerated with each instar. Firebrats can live up to 2 years at warm (90-98°F) temperatures.

B. T. campbelli - Little is known of this species but its life cycle resembles that of the firebrat.

C. Silverfish - Eggs are deposited in crevices or under objects singly or in groups of 2 or 3. The female deposits 1-3 eggs per day or at irregular intervals of up to several weeks depending upon availability of food. Eggs hatch at temperatures of 72-90°F (22-32°C). Eggs hatch in 43 days at 72°F to 19 days at 90°F. Females may reproduce at 3-4 months of age. Nymphs are 2 mm in size and scaleless when hatched. Scales develop in the 3rd instar. The first instar lasts 7-10 days; successive instars are 2-3 weeks long. Adults may live up to 3 1/2 years, but most live 2 years under favorable conditions (72-80°F, RH 75-97%). Silverfish may pass through up to 50 instars in their lifetimes.

D. Fourlined silverfish - Life cycle is similar to that of the silverfish but not as limited by temperature and moisture.

E. Gray silverfish - Eggs are deposited in cracks in groups of 2-20. Eggs hatch in about 60 days at room temperature. Nymphs are scaleless when hatched. Scales appear in the 4th instar, sexual maturity is reached in 2-3 years. This species may live up to 5 years.

F. A. collaris - Little is known of life cycle; may resemble that of silverfish.

6. Seasonal Abundance:

In heated buildings, silverfish are limited only by food. Numbers vary little throughout the year. Silverfish may enter buildings by way of boxes, book or other materials carried inside.

7. Response To Environmental Factors:

Temperature is the most important factor influencing the thysanurans. Low temperatures result in high mortalities, especially among nymphs. Mallis (1982) reports that temperatures below freezing or above 112°F result in 100% mortality in firebrat nymphs. Similar ranges can be expected for other species. Low relative humidities may reduce population growth or eliminate silverfish.

8. Impact:

Thysanurans are primarily important as archival pests although they may infest foodstuffs. Individuals are long lived and reproduction is moderate. Populations grow slowly, but large populations can cause severe damage to paper and paper products.

9. Natural Enemies:

No information concerning natural enemies of the Thysanura was found.

II. SILVERFISH MANAGEMENT

. Population Monitoring Techniques:

Monitoring is best performed by detecting damage caused by silverfish (Mallis, 1982).

Book binding will show minute scrapings. The sizing of paper will be removed in irregular fashion and the edges of the paper will appear notched. In cases of severe injury, irregular holes will be eaten directly through paper. Other signs of feeding include feces, scales, and small yellow stains.

Active infestations can be detected by observing the small, dark feces which are visible to the eye as well as scales which are visible through a hand lens (Mallis and Caur, 1982).

A piece of paper may be coated with a thin layer of flour paste and placed in areas of suspected infestation for a week. If silverfish are in the vicinity, the paper will show feeding marks.

A small jar (baby food jars are good) coated on the inside with a thin dusting of flour and with tape or soft paper on the outside (to provide a climbing surface), placed in an area of suspected infestation, may be an effective monitoring trap for most silverfish. (Mallis and Caur, 1982).

. Threshold/ Action Population Level:

Due to their small size and reclusive nature, silverfish are seldom seen. One adult captured in a jar trap or feeding signs on flour cards may be indicative of a population which requires control.

. Management Alternatives - Non-chemical:

Warm temperatures and high relative humidities favor most silverfish populations. Controlling or eliminating moisture in areas infested with silverfish can reduce populations as silverfish are usually indicative of a moisture problem. Use of air conditioning or a dehumidifier to lower temperatures and relative humidities, particularly where paper or books are stored, can also help to reduce populations by lowering the reproductive rate.

Sealing cracks and crevices where silverfish hide and breed also reduces populations by reducing suitable habitat. If sealing or caulking are not possible, cracks and crevices (particularly around bookcases) should be regularly vacuumed to pick up eggs, nymphs and adults. Good sanitation practices should be followed; all valuable paper products such as books and documents should be placed in tightly sealed containers or cabinets. If this is

not possible, access by silverfish to potential food sources should be cut off by the removal of food and breeding sites such as empty cardboard boxes and other scrap paper.

Baited traps have not been shown to be effective in control due to the limited attraction of baits; direct contact by antenna is required before feeding commences.

4. Management Alternatives - Chemical:

The following pesticides are recommended for use on silverfish in NPS areas.

- Silica aerogels
- Boric acid
- Diazinon
- Dichlorvos
- Pyrethrins

Silica aerogels such as Dri-die 67® or Dryone® have been used with excellent results. Boric acid is also effective.

Pesticides for silverfish should be applied in the same manner and with the same thoroughness as for cockroaches; boric acid should be spread thinly in areas where silverfish may be present. Cracks and crevices should be treated. Programs for roach control often eliminate silverfish as well (Ebeling, 1977).

Silverfish found in attics should be treated with silica aerogels which give lasting control in dry areas.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

5. Summary of Management Recommendations:

1. Routinely monitor in high risk areas by looking for damage, droppings, and scales, or place flour paste baits or jar traps.

2. Sanitation: reduce harborage by enclosing vulnerable and valuable materials in insect-tight containers.

3. Reduce relative humidity or raise or lower temperatures.

4. Provide chemical control with approved pesticides.

IV. BIBLIOGRAPHY

A copy of the following articles may be obtained by contacting the IPM Coordinator, WASO.

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NATIONAL PARK SERVICE
IPM Information Package

BLACKSPOT AND POWDERY MILDEW

Final Report

30 September 1984

Submitted To:

William E. Currie
U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

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Rockville, Maryland 20852

CONTENTS

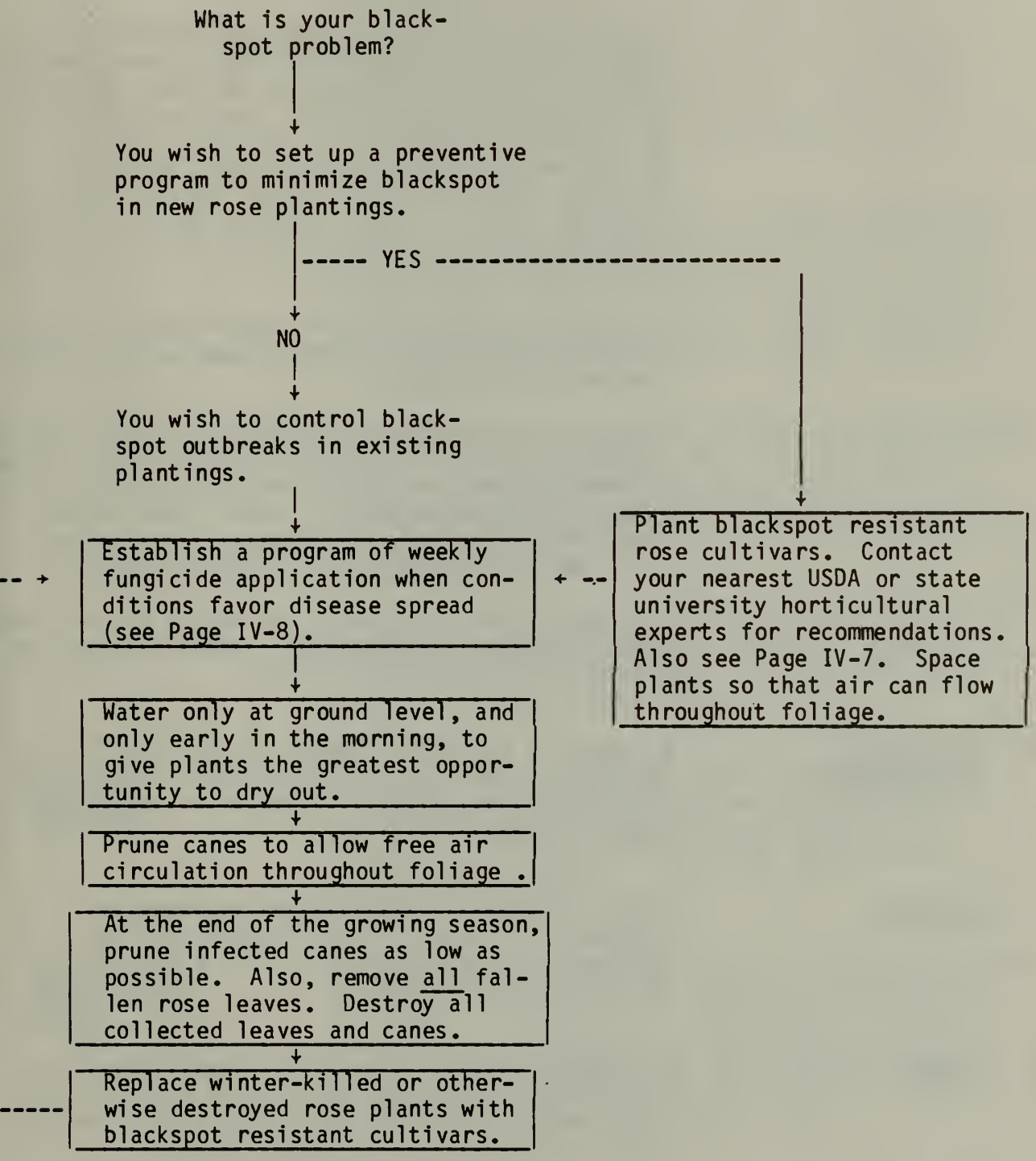
Section		Page
I.	BLACKSPOT DECISION TREE	IV-3
II.	BLACKSPOT BIOLOGY AND ECOLOGY	
1.	Disease Described	IV-4
2.	Geographic Distribution	IV-4
3.	Habitat	IV-4
4.	Hosts	IV-4
5.	Disease Cycle	IV-5
6.	Seasonal Abundance	IV-5
7.	Responses to Environmental Factors	IV-5
8.	Impact of Blackspot	IV-6
8.1.	Direct Impact	IV-6
8.2.	Indirect Impact	IV-6
9.	Natural Enemies	IV-6
III.	BLACKSPOT MANAGEMENT	
1.	Population Monitoring Techniques	IV-7
2.	Threshold/Action Population Level	IV-7
3.	Management Alternatives - Nonchemical	IV-7
4.	Management Alternatives - Chemical	IV-8
5.	Summary of Management Recommendations	IV-8
IV.	BLACKSPOT BIBLIOGRAPHY	IV-9
V.	POWDERY MILDEW IPM DECISION TREE	IV-10
VI.	POWDERY MILDEW BIOLOGY AND ECOLOGY	
1.	Diseases Described	IV-11
2.	Geographic Distribution	IV-12
3.	Habitat	IV-12
4.	Hosts	IV-12
5.	Disease Cycles	IV-13
6.	Seasonal Abundance	IV-14
7.	Responses to Environmental Factors	IV-14
8.	Impact of Powdery Mildews	IV-14
8.1.	Direct Impact	IV-14
8.2.	Indirect Impact	IV-14
9.	Natural Enemies	IV-15

CONTENTS, CONTINUED

Section		Page
VII.	POWDERY MILDEW MANAGEMENT	
	1. Population Monitoring Techniques	IV-16
	2. Threshold/Action Population Level	IV-16
	3. Management Alternatives - Nonchemical	IV-16
	4. Management Alternatives - Chemical	IV-16
	5. Summary of Management Recommendations	IV-17
VIII.	POWDERY MILDEW BIBLIOGRAPHY	IV-18

I. BLACKSPOT IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All uses of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


What is your blackspot problem?
You wish to set up a preventive program to minimize blackspot in new rose plantings.
YES
NO
You wish to control blackspot outbreaks in existing plantings.
Plant blackspot resistant rose cultivars. Contact your nearest USDA or state university horticultural experts for recommendations. Also see Page IV-7. Space plants so that air can flow throughout foliage.
Establish a program of weekly fungicide application when conditions favor disease spread (see Page IV-8).
Water only at ground level, and only early in the morning, to give plants the greatest opportunity to dry out.
Prune canes to allow free air circulation throughout foliage .
At the end of the growing season, prune infected canes as low as possible. Also, remove all fallen rose leaves. Destroy all collected leaves and canes.
Replace winter-killed or otherwise destroyed rose plants with blackspot resistant cultivars.

II. BLACKSPOT BIOLOGY AND ECOLOGY

1. Disease Described:

Blackspot - Caused by the fungus Diplocarpon rosae. The asexual form of the fungus, Marssonina rosae, is more commonly observed. Since the pathogen is microscopic and requires specialized equipment to grow and be observed in culture, it will not be described here. See Nelson (1975), Westcott (1960), or Horst (1983) for a complete description.

Symptoms of blackspot of roses include brown to black circular to irregular spots on canes, petioles, peduncles, fruit, flower parts, but most often on the upper surfaces of leaves. The spots may be up to 1/2" in diameter, and have feathery or fringed margins, due to the presence of fungal mycelium under the leaf surface. Small black pustules (acervuli) can be seen on the surface of each spot. White, slimy spore masses are produced at the tips of the pustules.

Leaf tissue surrounding the spots becomes yellow; the yellowing eventually spreads throughout each affected leaflet until it drops.

First-year canes of highly susceptible rose cultivars show purple-red, irregularly-shaped, raised blotches on immature wood, especially on succulent basal shoots late in the growing season. These spots become black and are dotted with pustules. Lesions are often small, and do not kill affected branches.

Petioles, peduncles, fruit, and sepals develop symptoms similar to leaf symptoms. Petals may be distorted and bear red spots with pustules.

2. Geographic Distribution:

D. rosae is native to Europe. It was first observed in the U.S. in Philadelphia, Pennsylvania, in 1831 (Nelson, 1975). Blackspot is reportedly found throughout the U.S.

3. Habitat:

Occurs throughout the temperate and tropical regions of the world, but it occurs with the greatest intensity where rainfall is heavy (e.g., the Pacific Northwest).

4. Hosts:

D. rosae attacks only species of genus Rosa. So-called black spot diseases of other plants (e.g., elm, cactus, delphinium, goldenrod, holly, raspberry) are caused by unrelated organisms.

Disease Cycle:

A. Overwintering - Both sexual spores (which occur rarely) and asexual spores can survive winter conditions. In addition, acervuli in fallen leaves and stem lesions can overwinter to produce new spores in the spring.

B. Distribution to Hosts - Sexual spores are produced in specialized fruiting bodies (apothecia) on fallen leaves; they are forcibly ejected into the air in the spring, and can be carried by wind to new infection sites. Asexual spores are formed in slimy masses, so must be carried to new hosts by rainsplash and/or in irrigation water (e.g., during overhead sprinkling).

C. Growth Within The Host - Under favorable conditions, spores can germinate and penetrate host cell walls within 13 hours after landing on an infection site. Mycelium grows intercellularly and under the surface cuticle, and produces absorbing organs (haustoria) within host cells; the haustoria obtain nutrients from the infected cells.

Symptom production may occur between three and sixteen days after infection. The yellowing and falling of diseased leaves is caused by the production of ethylene gas by affected leaf tissue; the observed symptoms are well-known responses of plant tissue to exposure to ethylene.

Acervuli form between the leaf epidermis and cuticle between 11 and 30 days after infection. Apothecia form only in leaves that have fallen; additional acervuli may also form then.

Seasonal Abundance:

Blackspot is most abundant during the late spring, early summer, late summer, and early fall. Hot summer temperatures and cold winter weather are unfavorable for fungal growth and disease development.

Responses to Environmental Factors:

Asexual spores must be wetted for at least 5 minutes before they can germinate, even at 100% relative humidity. Conidia must be continuously wet for at least 7 hr for infection to occur (Horst, 1983). The optimum temperature for spore germination is 64°F, and that for disease development is 75°F. No infection occurs in dry air.

8. Impact of Blackspot:

8.1	Direct Impact:	The most important effect of blackspot is defoliation of rose plants, which causes a reduction in photosynthesis. This reduces plant vigor and flower production. Heavy infections may cause deformation of flowers. Blackspot injury reduces the capacity of affected plants to store carbohydrates, increasing the susceptibility to winter kill. A severe attack in one growing season leads to poor vigor the following season in those plants that are not killed during the winter.
8.2	Indirect Impact:	Visitor dissatisfaction with heavily infested areas may occur.

9. Natural Enemies: Few data are available concerning natural enemies of D. rosae. No organisms are known to exert useful levels of blackspot control.

III. BLACKSPOT MANAGEMENT

1. Population Monitoring Techniques:

The most effective technique for monitoring D. rosae populations is visual inspection of susceptible rose plants for symptoms. Inspections should be conducted regularly during the growing season. Surveys should begin when favorable spore germination conditions occur (i.e., when temperatures rise to 60°F, and when free water or high humidity [above 90%] is present).

2. Threshold/ Action Population Level:

Since even slight D. rosae attacks can cause defoliation, flower malformation, and production of new spores, tolerable levels of black spot will most likely be very low. Correlation of past disease levels (e.g., as percentages of infected leaves per plant) with plant replacement records may provide information for setting action levels.

3. Management Alternatives-Nonchemical:

A. Sanitation - All fallen rose leaves should be gathered and removed at the end of each growing season, to prevent spore release from them the following spring. At the same time, any infected canes should be pruned as extensively as possible and removed, to eliminate any spore-bearing lesions they may bear.

B. Irrigation - Free water should not be allowed to accumulate on rose leaves. Irrigation should be from the ground or by hand-held wand (at ground level). Watering should be done early in the day to prevent water from remaining on leaves and promoting spore germination. Drip irrigation, which uses less water than other methods, and which prevents contact of foliar surfaces with water, should be considered for rose plantings.

C. Ventilation - Rose plantings should not be so dense that air currents cannot circulate among branches to promote evaporation of accumulated water. Plants should be spaced and pruned to allow free air circulation within plantings.

D. Resistance - Although most roses are susceptible to D. rosae, certain cultivars are more resistant than others to the pathogen. Contact your nearest USDA Extension Service personnel or state university

horticultural experts for information on currently available resistant cultivars for your area (also see Horst 1983).

4. Management Alternatives-Chemical:

Since D. rosae spreads within host tissues, existing infections are not affected by application of most fungicides (which cannot penetrate the leaf surface). Therefore, weekly fungicide applications are required to prevent D. rosae from penetrating the host cuticle and establishing new infections. Folpet or triforine should be applied at weekly intervals when weather conditions favor spore germination (i.e., when temperatures are above 60°F, and when the relative humidity is above 90% [or free water is available for extended periods]).

5. Summary of Management Recommendations:

A. Use resistant rose cultivars wherever possible.

B. Space plants and prune stems to ensure air circulation throughout rose foliage.

C. Gather and destroy all fallen rose leaves at the end of the growing season. At the same time, cut all infected canes as close to the ground as possible, and destroy cut portions.

D. Water roses at ground level; water only during early morning, to allow wet foliage to dry.

E. Use recommended protectant fungicides to prevent or reduce disease spread. Apply once each week while conditions are favorable for fungus growth. Apply as soon after rain as possible.

IV. BLACKSPOT BIBLIOGRAPHY

Copies of the following articles may be obtained by contacting the IPM Coordinator, WASO.

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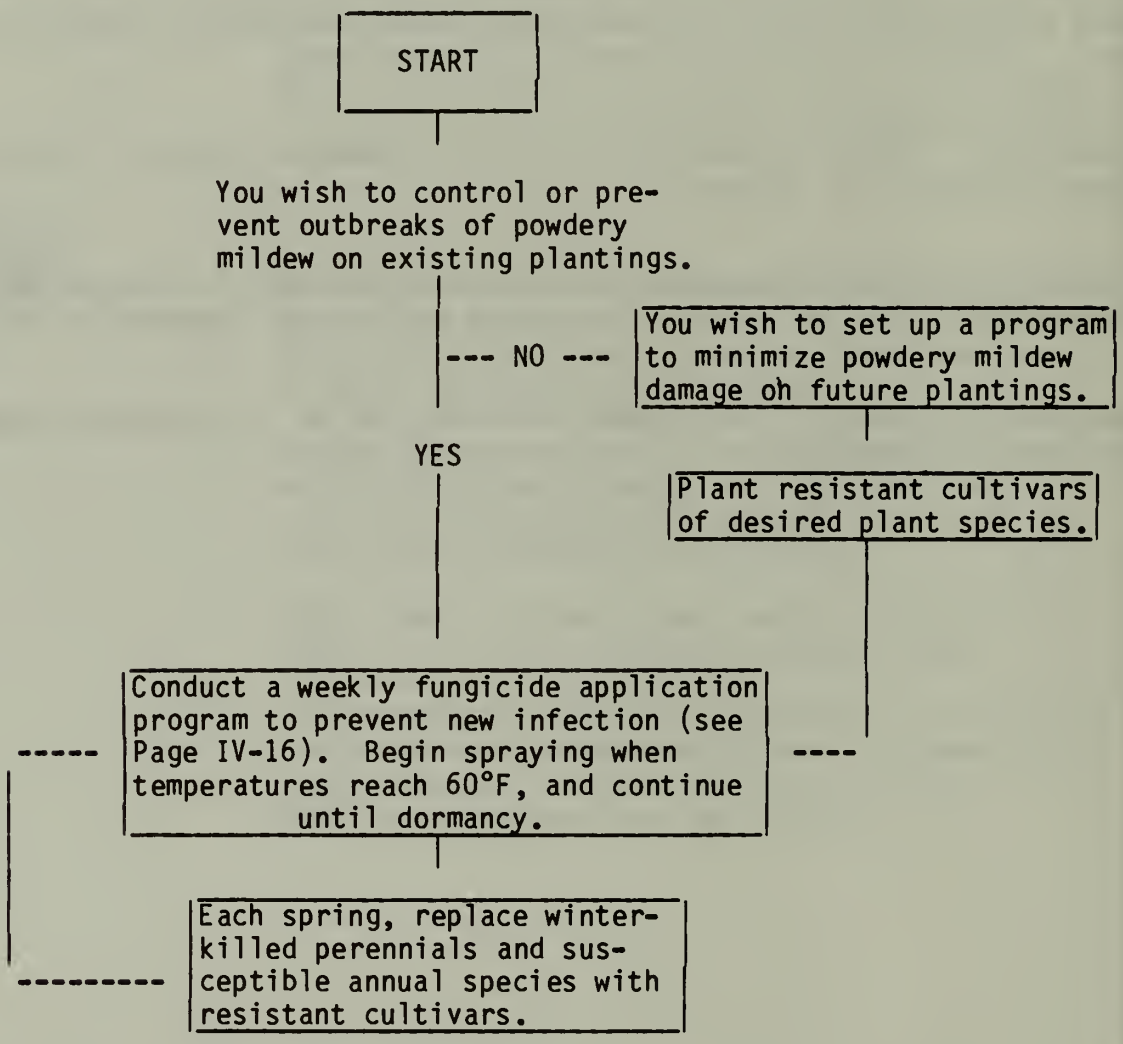
V. POWDERY MILDEW IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All uses of pesticide must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


START
You wish to control or prevent outbreaks of powdery mildew on existing plantings.
--- NO ---
You wish to set up a program to minimize powdery mildew damage on future plantings.
YES
Plant resistant cultivars of desired plant species.
Conduct a weekly fungicide application program to prevent new infection (see Page IV-16). Begin spraying when temperatures reach 60°F, and continue until dormancy.
Each spring, replace winter-killed perennials and susceptible annual species with resistant cultivars.

I. BIOLOGY AND ECOLOGY OF POWDERY MILDEWS

. Diseases Described:

Powdery mildew diseases are caused by fungi of the family Erysiphaceae in the class Ascomycetes. The powdery mildew fungi of North America include the following:

A. *Erysiphe cichoracearum*;

B. *Erysiphe graminis*;

C. *Erysiphe polygoni*;

D. *Microsphaera alni*;

E. *Phyllactinia corylea*;

F. *Podosphaera leucotricha*;

G. *Podosphaera oxyacanthae*;

H. *Sphaerotheca macularis*;

I. *Sphaerotheca mors-uvae*;

J. *Sphaerotheca pannosa*; and

K. *Uncinula necator*.

Fungal structures are microscopic, thus they will not be described here. For detailed descriptions of these fungi, see Agrios (1978), Alexopoulos (1962), or Yarwood (1957).

Powdery mildews may be the most common and widespread of all plant diseases. They are characterized by the development of spots or patches of gray to white, powdery fungus mycelium on young plant tissues; leaves, flowers, fruit or stems may become completely covered by the powdery growth. Young plant tissues may show slightly raised, blisterlike, discolored areas. Young leaves and shoots may be curved, distorted, or deformed. Fungal growth is most common on the undersides of leaves, but under shaded conditions all surfaces will be colonized. Late in the growing season, tiny pinhead-sized sexual fruiting bodies (cleistothecia) form singly or in clusters

in older infected areas; white at first, they become yellowish, brown, and finally black as they mature.

Additional symptoms and signs of powdery mildew of rose (caused by S. pannosa) include the formation of small pink to yellow blisters on mature canes; these enlarge, turning black as the disease progresses. Infected shoots are curved, distorted and stunted. Infected flower buds fail to open fully; petals become discolored and distorted. Late-season fungal growth becomes thicker and felt-like with brown to black cleistothecia.

Additional signs and symptoms of powdery mildew of peach (caused by S. pannosa) include distortion and drying of infected flower parts, and failure of flowers to open (or open fully). Infected fruits show white circular spots which may spread over most or all of the fruit surface. The fruits become pinkish, and finally dark brown; the fruit surface becomes leathery and hard, and may be swollen or cracked.

Additional signs and symptoms of powdery mildew of grapes (caused by U. necator) include scarring and cracking of fruit. Young colonies on leaves are yellowish patches about 1/4" in diameter. Mature canes develop red, speckled, stainlike infection scars, which are visible the winter after infection.

2. Geographic Distribution:

Powdery mildews are found wherever high relative humidity can occur (for even short periods) at leaf surfaces. They occur throughout North America, including Alaska, and may be most abundant in semiarid regions.

3. Habitat:

Powdery mildew fungi can occur throughout the ranges of their hosts. They are obligate parasites; i.e., they can only grow while in contact with a host plant.

4. Hosts:

A. E. cichoracearum - Attacks begonia, chrysanthemum, cosmos, cucurbits, dahlia, flax, lettuce, phlox, and zinnia.

B. E. graminis - Attacks cereals and grasses.

C. E. polygoni - Attacks beans, soybeans, clovers, other legumes, beets, crucifers (cabbage, etc.), cucumber, cantaloupe, delphinium, and hydrangea. Over 350 host species are known.

D. M. alni - Attacks blueberries, catalpa, elm, liacs, linden, oak, rhododendron, and sweet pea.

E. Phyllactinia corylea - Attacks catalpa, elm, maple, and oak.

F. P. leucotricha - Attacks apple, pear, and quince.

G. P. oxyacanthae - Attacks apricot, cherry, peach, and plum.

H. S. macularis - Attacks strawberry.

I. S. mors-uvae - Attacks current and gooseberry.

J. S. pannosa - Attacks rose, peach, and apricot.

K. U. necator - Attacks grape, horsechestnut, and linden.

5. Disease Cycles:

Since the life cycles of the powdery mildew fungi are similar to each other, only a general life cycle is presented here.

The powdery mildew fungi overwinter as dormant branches (hyphae) in host buds, although some species (e.g., S. pannosa on roses) develop sexual fruiting bodies (cleistothecia) on host leaves, petals and stems late in the growing season. If the fungus overwinters as cleistothecia, then spread in the early spring is by sexual spores (ascospores) which are forcibly ejected from the cleistothecia after the fruiting bodies absorb atmospheric water, swell, and crack open. If the fungus overwinters as hyphae, spread is by single-celled, asexual spores (conidia) produced at the tips of aerial hyphae.

Spores are carried by wind to young plant tissues, and germinate if the temperature and relative humidity are proper. The first hypha produced (the germ tube) penetrates the host plant's cuticle, and enters an epidermal cell, forming a globular feeding organ (haustorium) within the still-living cell. Surface hyphae are produced, and spread across the plant surface, sending more haustoria into additional host cells.

Feeding by the fungus weakens host cells, reduces photosynthesis, and may cause uneven growth of affected tissues, leading to deformities of the affected plant organ(s).

The fungus produces specialized upright hyphae which bear chains of 5-10 conidia, giving the aerial growth its characteristic powdery appearance. The conidia are picked up by wind currents, which carry them to new infection sites on the same or other host plants.

Late in the growing season, fungal spore production slows and eventually stops, as growth conditions become less favorable. Sexual reproduction of the fungus then occurs, and round cleistothecia form within mycelial mats. Ascospores are produced within the cleistothecia in the late fall, or in some cases in the early spring of the following year. In warm areas, cleistothecia may not form at all (Yarwood, 1957).

6. Seasonal Abundance:

Powdery mildews occur from late spring to mid-fall (when temperatures are above 60°F).

7. Responses to Environmental Factors:

Spores germinate at temperatures of 60-75°F and over a wide range of relative humidities. Free water is not necessary for spore germination. Conidial formation, growth; release from conidiophores, and germination follow daily cycles (Yarwood, 1957). Cessation of conidia formation, and initiation of sexual reproduction apparently depend on the temperature reductions which occur in late summer and fall.

8. Impact of Powdery Mildews:

8.1 Direct Impact:

Infected ornamental plants may develop unsightly distorted or deformed growth. Infected flowers may be discolored, distorted, and unable to open properly. Infected fruit become unattractive and inedible. infected foliage may fall early.

8.2 Indirect Impact:

Infected plants are often weakened, and may become susceptible to injury by other pests, and to winter injury. Visitor dissatisfaction with areas showing symptoms of heavy attack may occur.

9. Natural Enemies: Although some natural enemies of the powdery mildew fungi may occur (e.g., spore-eating arthropods), such organisms do not exert useful levels of control.

VII. POWDERY MILDEW MANAGEMENT

1. Population Monitoring Techniques:

Currently, the only available monitoring technique for powdery mildews is visual observation of plants for symptoms and signs of disease. Visual surveys should be conducted throughout the growing season, and records of all observations should be maintained. Disease severity can be noted on the basis of approximate number of infected plants, and/or percentages of infected foliage, fruit, or flowers.

2. Threshold/ Action Population Levels:

While slight infection may not be noticeable on park plantings, heavier attack may produce obvious foliar mildew, flower and fruit damage, and increased risk of susceptibility to attack by other pests. Correlation of observed levels of powdery mildew with incidence of visitor complaints or damage to plantings may provide a basis for setting action (treatment) levels.

3. Management Alternatives - Nonchemical

A. Resistance - Resistant cultivars of many powdery mildew-susceptible plant species are becoming available; contact your local USDA representatives or state university horticultural experts for recommendations for your area. Resistance is not immunity, however, and resistant plants will be attacked under favorable conditions.

B. Sanitation - Sanitation procedures such as removal and destruction of infected leaves and stems may be useful, but will not prevent reinfestation, since the fungus survives in host buds through adverse conditions. Removal of wild hosts, while theoretically useful in protecting annual plants from sources of infection left over from the previous growing season, is of little benefit due to the wide host range of some mildew species (e.g., E. polygoni), and to the ability of spores to travel over long distances in wind currents.

4. Management Alternatives - Chemical:

The only effective means to reduce powdery mildew is to prevent infection. Weekly (or more frequent, during periods of rapid plant growth, fluctuating temperatures, or frequent rains) applications of folpet or triforine will prevent new infection from taking place, provided complete coverage of foliage is achieved. Follow label directions when using these products. Contact your NPS Regional IPM Coordinator for guidance in selecting the best fungicide for your particular requirements.

5. Summary of Management Recommendations:

A. Use powdery mildew-resistant plant cultivars.

B. Treat plantings weekly with a recommended fungicide, throughout the growing season.

C. Remove and destroy infected stems and leaves.

VIII. POWDERY MILDEW BIBLIOGRAPHY

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NATIONAL PARK SERVICE
IPM Information Package

SOUTHERN PINE BEETLE

Final Report

30 September 1984

Submitted To:

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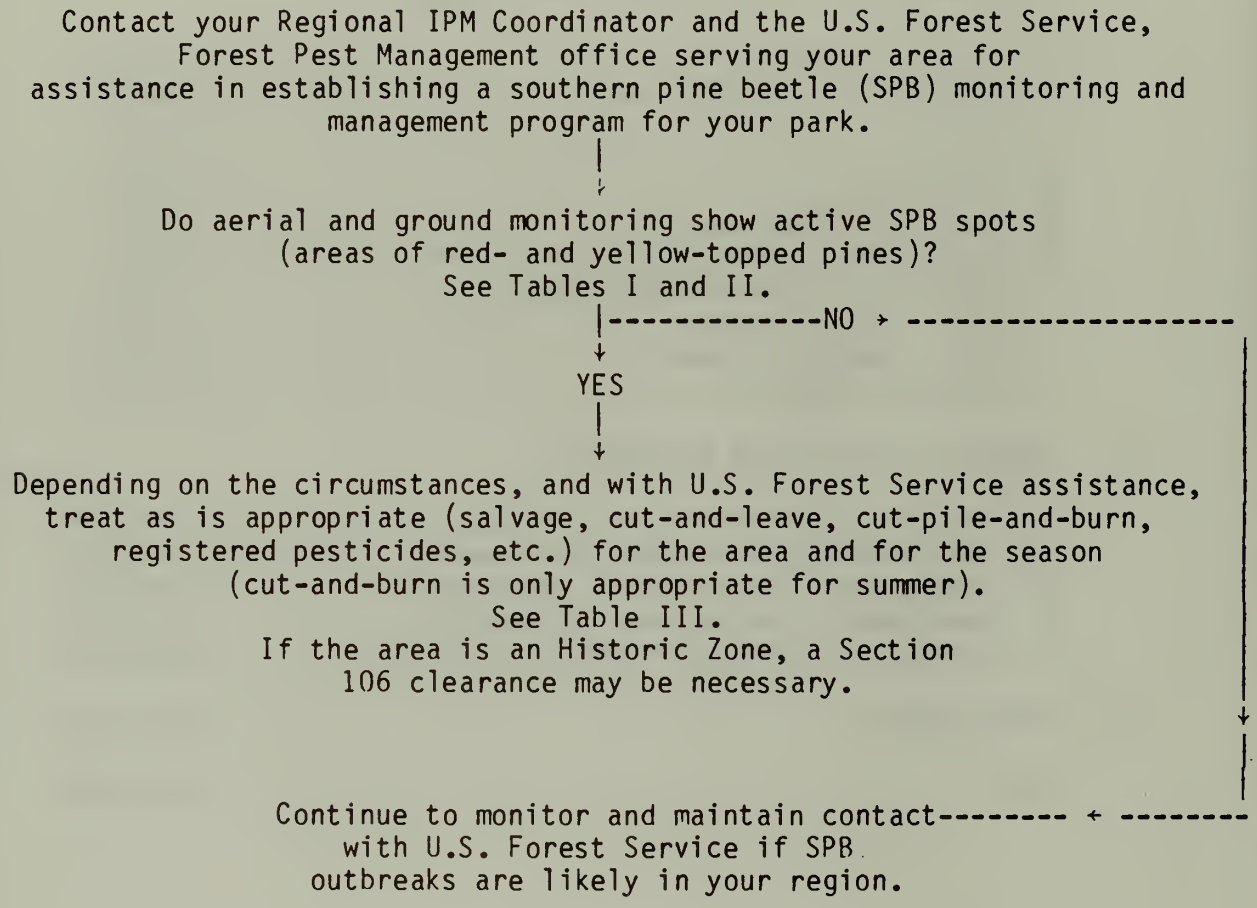
CONTENTS

Section		Page
I.	SOUTHERN PINE BEETLE IPM DECISION TREE	XXXI-2
II.	SOUTHERN PINE BEETLE BIOLOGY AND ECOLOGY	
	1. Species Described	XXXI-3
	2. Geographic Distribution	XXXI-3
	3. Habitat	XXXI-4
	4. Hosts	XXXI-4
	5. Life Cycle	XXXI-4
	6. Seasonal Abundance	XXXI-6
	7. Responses to Environmental Factors	XXXI-7
	8. Impact of Southern Pine Beetle	XXXI-8
	8.1. Direct Impact	XXXI-8
	8.2. Indirect Impact	XXXI-8
	9. Natural Enemies	XXXI-8
III.	SOUTHERN PINE BEETLE MANAGEMENT	
	1. Population Monitoring Techniques	XXXI-10
	2. Threshold/Action Population Levels	XXXI-10
	3. Management Alternatives - Nonchemical	XXXI-11
	4. Management Alternatives - Chemical	XXXI-14
	5. Summary of Management Recommendations	XXXI-15
IV.	BIBLIOGRAPHY	XXXI-16
	TABLES	XXXI-20

I. SOUTHERN PINE BEETLE IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All uses of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


Contact your Regional IPM Coordinator and the U.S. Forest Service, Forest Pest Management office serving your area for assistance in establishing a southern pine beetle (SPB) monitoring and management program for your park.
Do aerial and ground monitoring show active SPB spots (areas of red- and yellow-topped pines)? See Tables I and II.
NO
YES
Depending on the circumstances, and with U.S. Forest Service assistance, treat as is appropriate (salvage, cut-and-leave, cut-pile-and-burn, registered pesticides, etc.) for the area and for the season (cut-and-burn is only appropriate for summer). See Table III. If the area is an Historic Zone, a Section 106 clearance may be necessary.
Continue to monitor and maintain contact with U.S. Forest Service if SPB outbreaks are likely in your region.

. SOUTHERN PINE BEETLE BIOLOGY AND ECOLOGY

Species Described:

Southern pine beetle (SPB), Dendroctonus frontalis Zimmerman, is a member of the bark beetle family Scolytidae.

Adults are small, somewhat stout, cylindrical insects 3 mm to 4 mm long. Antennae have 7 segments, and are elbowed with the outer segments enlarged and club-like. The head, partially hidden from above by the thorax, has strong gouge-like jaws (mandibles) for boring in wood. The exoskeleton is shiny and relatively smooth. Adults are dark brown to black in color.

Eggs are oval with round ends, 1.5 mm by 1 mm in size. They are yellowish white and hatch in 3 to 11 days, at temperature ranges of 15°-30°C (59°-86°F), with development faster at higher temperatures. At lower temperatures, development takes longer, up to 34 days at 10°C (50°F).

Larvae are yellowish white and go through 4 stages (instars). Each instar lasts 7-13 days. Larvae range in size from 2 mm when newly hatched to 5-7 mm in the fourth instar. Larvae feed on inner bark tissues (cambium layer).

Pupation occurs within the host tree. Pupae are yellowish white, and 3-4 mm in length. The pupal stage lasts 5-17 days at a temperature range of 15-30°C (59°-86°F), with development faster at higher temperatures. Young adults are yellowish tan in color. As the cuticle hardens, it becomes darker, a process which may take up to 14 days. The fully developed beetle is dark brown to black when it emerges from the host tree (Thatcher et al. 1981).

See Thatcher et al. (1981) for a photographic guide to all stages of the southern pine beetle.

Geographic Distribution:

A native insect, SPB occurs in North America in a range roughly similar to that of its preferred hosts, shortleaf and loblolly pines, i.e., south of a line from southern New Jersey to central Texas. SPB also occurs in Arizona through Central America to northern Nicaragua. In the U.S., outbreaks have occured in Texas, Oklahoma, Arkansas, Louisiana, Kentucky, Tennessee, Alabama, Mississippi, Florida, Georgia, North Carolina, South Carolina, and Virginia. Infestations have also been reported from Delaware,

Pennsylvania, Ohio, New Jersey, Indiana, Illinois, and Missouri.

See Thatcher et al. (1981), for distribution maps and information on outbreak ranges.

3. Habitat:

Attacking adult beetles bore through the bark. Egg galleries are constructed in the cambium region. The resulting larvae feed in the cambium, complete their development, and pupate in the bark. SPB initially attack the tree at mid-bole; later attacks occur above and below (Thatcher et al. 1981).

4. Hosts:

SPB can attack and kill pines of all species and all sizes. Small trees of less than 2 inches in diameter (under 15 years old) are seldom attacked. Normally, it attacks overmature trees, or stressed trees such as wind-falls, root rotted trees, or trees weakened by drought, lightning, fires, other insects, or damage caused by human activities. In outbreaks, however, SPB attacks and kills healthy pines of all species. Although the mechanisms of outbreaks are poorly understood, it is thought that poor stand vigor or stress resulting from overmaturity, drought, or ice damage from previous winters are major triggering factors.

Primary hosts are believed to be loblolly, shortleaf, Virginia, and pitch pines. Other hosts include table mountain pine, longleaf pine, spruce pine, slash pine, Norway spruce, Japanese red pine, red pine and pond pine. In Arizona and New Mexico, SPB is known to attack ponderosa and Apache pines. Secondary hosts are usually attacked only during epidemics in primary hosts. Secondary hosts do not normally support epidemics. Infestations on white pine usually do not succeed because of heavy exudations of pitch. Beetles attack red spruce, but broods do not develop within the tree (Paine, 1981).

5. Life Cycles:

In order to understand the life cycle of SPB, a brief description of the cycle of colonization is required.

In colonization, newly emerged pioneer female beetles select and attack a suitable host. Odors from potential host trees are thought to attract pioneering females. Attacking females release aggregation pheromones, principally frontalin, which, with host odors, serves to attract other females as well as males to the tree. More males than females are

attracted in this initial aggregation (4:1 or 3:1 ratio). The initial attack and aggregation is on the midbole of the tree, from 5 to 20 feet from the ground. As more females arrive, more pheromones are released, and more SPB are attracted. Attacks spread up and down the bole from the initial site. Aggregation behavior follows a diurnal pattern; in summer, greatest activity occurs around 5 PM, while in spring, peak aggregation occurs around 10 AM and 5 PM. After a female arrives, she finds a crevice in the bark and bores in, releasing frontalin and trans-verbenol which enhances the aggregation effect of frontalin. As long as the tree resists attack by exuding resin, the female releases frontalin. When the female begins to feed on bark tissues, frontalin production stops. Pitch tubes are formed by the tree as a result of cut resin ducts under internal pressure. As more beetles attack, resin pressure drops, fewer tubes are formed and the tree becomes more susceptible. When entry into the tree is complete, the female releases small amounts of the pheromone verbenone which enhances existing pheromones and orients males to entry holes in the bark. When a male finds an entrance hole, he releases verbenone and endo-brevicomin which serves to balance the sex ratio of responding SPB to more nearly 1:1 by reducing host attraction to males. As the number of males on a host increases, so does the amount of verbenone and endo-brevicomin so beetles are deterred from the host and seek adjacent host trees, beginning the process anew.

Southern pine beetles are usually monogamous, (ie. a single female will mate with a single male within the host tree) but a single female may mate with up to 6 males in some situations. Mating occurs in the entrance galleries. Once mating has occured, the female constructs an S-shaped egg gallery by expanding the entrance gallery. As she bores through the wood, she packs the debris behind her, sometimes assisted by a male. The gallery, mined in the cambium layer diagonally across the wood grain, does not branch, and may cross other galleries in heavily infested trees. Galleries range in length from 10 to 24 cm. Shortly after the egg gallery is begun, the female cuts niches in the walls and deposits a single egg within each at intervals of 1-4 cm. Up to 30 eggs per gallery may be deposited at irregular intervals.

After ovipositing, parent adults reemerge from the host tree. Reemergence occurs 1-3 days after mass attack, mating, and oviposition. Reemerged adults attack new hosts, mate, and produce more eggs.

Larvae enter the cambium layer, making galleries perpendicular to the egg gallery. Larvae then enter the inner bark and feed outward until pupation in the outer bark.

Once adult development is complete, the beetle bores through the outer bark. Emergence patterns follow a normal (bell-shaped) distribution; all of the adults of a given brood may emerge in a 10-30 day period. Adults emerge in all seasons, attacking adjacent trees or dispersing to find suitable trees elsewhere. In winter, adults may reattack the same tree. SPB overwinter in all stages of development.

Generations overlap, with newly emerging adults and reemerging adults of the previous generations attacking hosts together.

Blue-stain fungus (Ceratocystis minor) is usually found in association with SPB. Its role in the SPB life cycle is not fully understood, but experiments have shown that colonies without blue-stain fungi produce fewer eggs than normal colonies. Blue-stain and other fungi may alter the phloem and make nutrients more available to larvae.

6. Seasonal Abundance:

There are several generations per year. In the northern part of the range as few as three generations per year are produced, while in the southern part of the range, up to nine generations per year are produced. In normal circumstances, the time from egg to reproductive adult is 26-54 days. In the Southern Appalachians overwintering adults emerge in mid-April, while adults from overwintering eggs emerge in late June. In North Carolina and further south, emergence is in March.

SPB spots (local areas of infestation) expand from late spring through summer, the result of adults emerging from killed trees and attacking trees on the leading edge of the spot. SPB appears to undergo population cycles of approximately 10 years in duration. During outbreaks, SPB are abundant, killing up to 50% of the stands of pines over large areas (Thatcher et al., 1981). In other years, they are extremely rare.

7. Response to Environmental Factors:

Environmental factors are believed to trigger SPB outbreaks. The precise mechanism involved is not yet fully understood, but any factor which contributes to tree stress or loss in vigor may be a factor in outbreaks.

Lack or overabundance of water is believed to be a principal factor in outbreaks (Kalkstein, 1976). Poor drainage resulting from abundant or superabundant rains is thought to trigger SPB outbreaks on the Western Gulf Coastal Plain, while drought is a major factor on the Altantic Coastal Plain. Wet soils cause a temporary decline in vigor in host stands, while drought causes lowered resin pressures, predisposing trees to attack.

The effect of temperature on outbreaks is not fully understood, but is thought to relate to water balance in host trees. Sustained low temperatures during winter months or abnormally high summer temperatures are believed to be detrimental to brood development and survival (W. Carothers, pers. com.).

Soil composition may be an indirect factor in SPB outbreaks. High clay content in shortleaf pine stands often is a contributing factor in littleleaf disease which stresses trees, allowing successful SPB attack (Hicks, 1981). Root rot, particularly annosus rot, has been found to be a causal factor in some SPB outbreaks. Root rot results in reduced tree growth and vigor (Kulhavy et al, 1984).

High stand density or overstocking results in poor tree vigor due to intraspecific competition for available resources, and predisposes trees to SPB attack (Belanger and Malac, 1980).

Other insects, especially other bark beetles (which may be only minor pests), may stress trees, allowing SPB to colonize.

Natural termination of an outbreak may be due to one or a combination of environmental factors such as cold winters, cool wet springs, pressure from natural enemies, and lack of suitable hosts. (W. Carothers, pers. com.)

8. Impact of Southern Pine Beetle:

8.1 Direct Impact:

The major direct effects of SPB are pine mortality and the reduction in grade and yield of beetle-killed sawlogs for commercial purposes. Pulpwood can be obtained from killed trees up to 2 years after tree death with little effect on the resulting paper (Leuschner, 1981).

8.2 Indirect Impact:

Aside from aesthetic impacts, few indirect effects of SPB have been noted. There is no reduction in water quality or quantity from sites attacked by SPB, and some wildlife species actually increase due to increases in edge effect and food sources due to increased understory growth.

In recreational areas, tree mortality results in less shade and increased understory growth, causing possible reduced site use, and results in a potential safety problem. The cost of removing hazard trees may be significant. Aesthetic values and potential increased fuel loads should also be considered.

Fungi are the primary cause of death in SPB infested trees, due to their blocking of phloem tubes around the circumference of the bole, preventing flow of nutrients to the tree. Fungi are carried from host to host in the gut or on the surface of adult beetles.

Populations of red cockaded woodpeckers, an endangered species, may be affected by loss of mature pines used for nesting habitat (Hooper et al., 1980).

9. Natural Enemies:

Many natural enemies of SPB have been described, including the following:

Predators - Over 100 species of arthropod predators of SBP are known. Among the more important are:

Checkered beetle (Thanasimus dubius) adults eat attacking SPB adults, and checkered beetle larvae within SPB galleries prey upon immature SPB. Checkered beetles respond to SPB pheromones and aggregate on trees under SPB attack. A related European species (T. formicarius), introduced in 1892, was the first insect imported for biological control of a forest insect pest (Craighead, 1950).

Beetles of the genus Corticeus feed on eggs and small larvae of SPB as well as on frass and bluestain fungi.

Two anthocorid bugs (Scoloposcelis mississippensis and Lyctocoris elongatus) prey upon all immature life stages of SPB within host galleries (Schmidt and Goyer, 1983).

See Goyer et al. (1980) for descriptive keys to arthropod associates of SPB.

At least 4 species of predatory mites are considered to have impacts on SPB populations (Moser, 1975).

Birds (especially woodpeckers) are very effective SPB predators, particularly in winter. In an east Texas study, it was found that four species of woodpecker (downy, hairy, pileated, and red-bellied) caused SPB mortalities of over 60% in some instances. Woodpecker densities are up to 50 times higher in SPB infested sites than in neighboring uninfested stands (Kroll et al., 1980). The effect of woodpeckers on SPB population dynamics is currently under study.

Parasitoids - Over 35 species of hymenopteran parasitoids in 8 different families are known to attack SPB in various life stages (Thatcher et al., 1981).

Pathogens - SPB is attacked by a variety of microorganisms which kill it or reduce its fecundity. Fungi and bacteria caused an average 22% mortality in one study (Moore, 1971). One species of parasitic nematode attacks the reproductive organs of adult SPB, rendering them sterile.

Competitors - SPB survival may be reduced through competition with other beetle species such as the southern pine sawyer (Monochamus titillator), a cerambycid beetle. Individual pines are killed by competing insects, but interspecific competition may slow or prevent SPB outbreaks.

Natural enemies have a greater role in regulating SPB populations in spring and early summer than in late summer and fall (Berisford, 1981).

III. SOUTHERN PINE BEETLE MANAGEMENT

Population Monitoring Techniques:

Monitoring for SPB is a two stage process as developed by the U.S. Forest Service; an aerial survey followed by a ground survey.

Aerial Survey - Aerial Surveys show spots (areas of dead and dying pines) from the air. Expanding spots are seen as groups of trees with red and yellow crowns.

Differences in crown colors can indicate the direction of the spread of SPB infestations. In summer, bare-crowned trees (dead pines which have lost their needles have been killed 8-12 weeks previous to observation. Red-topped trees are trees which, for the most part, no longer contain developing SPB broods, while yellow-topped trees have been more recently killed. Newly attacked trees on the leading edge of the spot are still green and indistinguishable from healthy trees.

Inactive spots have no yellow or green trees under attack, and no longer require control measures. (See Table I).

Ground checks - Ground checks for SPB should concentrate on spots designated as high and medium priority by aerial checks.

To ascertain if trees are infested with SPB, bark of red- and yellow-topped pines should be removed and inspected for the S-shaped galleries which are specific to SPB. On green-topped trees suspected of harboring SPB, and where galleries may not be fully developed, check for pitch tubes indicating entry holes and/or reddish boring dust in bark crevices, in spider webs, and on foliage of understory plants. (See Table II.)

2. **Threshold/ Action Population Levels:**

In SBP IPM, stands are rated on a risk basis. The higher the risk rating, the higher the control priority. Although risk ratings were developed for commerical timber operations, they are useful in IPM in non-timber regions.

Although it is difficult to establish thresholds, all spots of 10 or more trees should be reported. A very high percentage of spots with fewer than 10 active trees become inactive without any control.

Ground checks serve to rank stands in terms of risk and control priorities (see Table III).

Management Alternatives - Nonchemical:

Although southern pine beetle infestations should be allowed to occur unimpeded in natural zones, certain areas might require some management action including:

1. Areas with red cockaded woodpeckers;

2. Areas where killed trees may become hazards to visitors, park personnel, or to structures.

3. Sites where SPB infestations will kill or affect historic trees or disrupt the historic scene.

4. Infestations within the park that may spread to areas outside the park.

Most management strategies for SPB have been developed for timber producing areas. Circumstances may arise where commercial management techniques may be called for. Recommended practices include the following (treatment actions A-F are recommended for developed sites only):

A. Cultural control: Good silvicultural practices to maintain healthy stands contribute greatly to the reduction in incidence and severity of SPB outbreaks.

B. Favor most resistant species: Some pine species are more resistant to SPB attack than others, and susceptible species may change according to region. Selective cutting and replanting should favor resistant species (Belanger and Malac, 1980). See Table IV.

C. Monitoring of high-risk trees: Old pines or pines with damage from lightning, ice, hail, disease, or other disturbances, are extremely susceptible to attack and should be regularly monitored to detect any early attack (Thatcher et al, 1982). Trees in area-wide disturbances such as drought or flooding should be monitored from the air and ground for signs of early SPB attack (Belanger and Malac, 1980).

D. Maintenance of proper stand density: Thinning of pine stands increases growth and vigor, thereby reducing stress and susceptibility to SPB attack. Depending on site quality, basal areas of 80-100 ft^2/acre are recommended to reduce potential for SPB attack (Thatcher et al, 1982).

E. Management of species composition: SPB prefers pure pine stands; mixed stands of pine and hardwoods reduce chances of SPB attack. Mixed stands also support more species of plants and animals, including natural enemies of SPB.

F. Mechanical Control: Mechanical controls to stop the spread of SPB spots include the following (Billings, 1982):

1. Remove infested trees. When consistent with environmental and legal constraints, infested trees may be disposed of by commercial sale or salvage when accessible. Logging of the infested material should begin immediately. Contract time limits should ensure rapid removal.

   When practical, and if uninfested pine trees are present, a 40- to 70- foot buffer strip should be marked and cut adjacent to and ahead of the most recently infested trees. This practice is effective in reducing the possibility of "breakouts". When only a small volume of infested, merchantable material occurs in a spot, noninfested trees surrounding the spot may be marked to provide an operable cut.

   The order of priority of removing beetle-infested timber from a spot should be as follows:

   a. Trees in the buffer zone at the head(s) of the spot; if not removed within two weeks of marking, another visit and tally must be made in order to insure removal of all infested trees and an adequate buffer strip.

   b. Trees with fresh attack, and having young broods (usually the green, recently infested trees).

   c. Trees having nearly-developed broods (usually the red and fading trees).

   Remove infested trees by commercial sale or salvage procedures in accordance with National Park Service guidelines and procedures.

2. Pile-and-burn. Unmerchantable or inaccessible SPB infestations can be suppressed by cutting, piling, and thoroughly burning the bark of infested trees. The entire bark surface must be thoroughly burned to insure effective control. The order of priority for cutting, piling, and burning infested trees, particularly in the large spots, is the same as above. Cutting a buffer strip is not recommended. To reduce the possibility of "breakouts", every effort should be made to locate and treat all green infested trees during the piling and burning operation.

3. Cut-and-leave. This control tactic reduces losses from spot growth during the summer months. Cut-and-leave is designed to disrupt spot growth in small to medium-sized spots (40 active trees) by dispersing emerging beetles. These spots can be salvaged when markets or weather permit. Trees are still suitable for sale months after felling.

   The following procedure is to be followed when using cut-and-leave:

   a. Identify all active trees within the spot.

   b. Fell all active trees toward the center of the spot.

   c. Fell a horseshoe-shaped buffer of green, unifested trees around the most recently attacked trees. Leave cut trees lying on the ground with crown pointed toward the center of the spot. The buffer should be as wide as the average height of the trees in the stand.

   Cut-and-leave treatments should only be applied during the summer months (between June and October). Spots with 10 or more infested trees should be treated first. As time permits, spots with fewer than 10 infested trees should also be treated if they contain trees with fresh attacks. In these smaller infestations where a specific head is not distinguishable, an adequate buffer strip (equivalent to the avarage height of the stand) and all infested and green, uninfested trees within the spot should be felled.

   Re-examine treated areas. Re-examine areas where infested trees were removed by commercial sales or salvage, piled and burned, chemically treated, or cut and left within 2 or 3 weeks after treatment to check for additional infested trees. If additional trees are found, treat them.

In areas where infested trees have been cut or removed, stumps adjacent to living pine trees should be treated to control or prevent infestation by the root rot Fomes annosus.

In latitudes below 34 degrees N, trees cut between May and August do not have to be treated for Fomes annosus. This is because few spores are formed during this period, and high temperatures often kill spores that are produced. However, routine summer thinning in areas of SPB buildup is not recommended.

G. Biological Controls - While parasitoids, predators, and diseases of SPB play a role in reducing high populations, they alone have not been shown to terminate infestations. More likely they (in combination with abiotic factors and lack of sutiable hosts) cause infestations to decline.

Practices which favor natural enemy populations (e.g., leaving nesting snags for woodpeckers) are recommended. Evidence exists that greater numbers of predators and parasites emerge from stands treated by cut-and-leave than from standing infested trees.

4. Management Alternatives-Chemical:

SPB is a native organism and is protected in natural zones. Although NPS does not manage timber, management of SPB may be required to protect resources in Park Development, Special Use, or Historic Zones, or when SPB infestations threaten forested areas outside park boundaries. (See section III.3.)

Dursban (chlorpyrifos) is recommeded for SPB suppression in NPS areas.

The order of priority for cutting and spraying infested trees in large spots is the same as in the removal of infested trees by commercial sale. Cutting a buffer strip is not recommended. To reduce the possiblility of "breakouts", every effort should be made to locate and treat all green infested trees during the chemical control operation.

Cut, limb, and buck all infested trees into workable lengths. Spray the infested bark surface to the point of runoff. A compressed air sprayer (3-gallon capacity or equivalent) is an ideal applicator. Infested logs must be turned 2 or 3 times to insure complete treatment of infested bark. Spray stumps and bark removed by woodpeckers. Low pressure sprayers may be used to treat large, accessible infestations.

Never spray trees from which SPB brood has emerged. Natural enemies of the SPB in these trees can then complete their development.

Consult your regional IPM Coordinator to determine if pesticide treatment is recommended for your IPM program.

5. Summary of Management Recommendations:

The U.S. Forest Service provides technical assistance to other federal agencies on managing southen pine beetle. Each park manager should contact the NPS Regional IPM Coordinator and the U.S. Forest Service for assistance in setting up an IPM program for the southern pine beetle.

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Table I. SPB spot priority for ground check based on aerial surveys. (From Thatcher et al, 1982).

Priority for ground check:	Spot classification:
Priority 1 (high)	More yellow- than red-crowned trees. In dense natural pine stand or in area with past history of SPB outbreaks. Easy access or high salvageable volume. In plantation or other high value area. Threat to cross property and high value stands.
Priority 2 (breakout)	Yellow-crowned trees in spot previously reported controlled or inactive.
Priority 3 (medium)	More red- than yellow-crowned trees. Poor access or moderate salvageable volume.
Priority 4 (low)	Few yellow-crowned trees. Infested pines surrounded by hardwoods or open land. Difficult to locate on ground because of small size or inaccessibility. In unmerchantable timber or with low salvageable volume.

Table II. Symptoms associated with southern pine beetle-attacked trees in various stages of deterioration. (From Thatcher et al., 1982).

Stage	Tree part to be examined for symptoms	Symptoms or characteristics of SPB infestation
1. Trees with fresh SPB attacks	Foliage color	Green
	Pitch tubes	Soft, white or light pink
	Checkered beetles	Red, white and black adults crawling on bark
	Bark	Tight, hard to remove
	Color of wood surface	White, except close to new galleries
	Exit holes	None
	Boring dust	None to light scattering at base of tree
2. Trees with developing SPB broods	Foliage color	Green trees with larvae; needles fade to yellow before brood emerges
	Pitch tubes	Hardened, white
	Checkered beetles	Pink or red larvae about 1/2 inch long in SPB galleries
	Bark	Loose, peels easily
	Color of wood surface	Light brown with blue or black sections
	Exit holes	Few, associated with adult reemergence
	Boring dust	White, localized in areas around base of trees

Table II. (cont.)

Stage	Tree part to be examined for symptoms	Symptoms or characteristics of SPB infestation
3. Vacated trees	Foliage color	Red, needles falling
	Pitch tubes	Hard, yellow, crumble easily
	Checkered beetles	Larvae and pupae are purple; occur in pockets in loose bark
	Bark	Very loose, easily removed
	Color of wood surface	Dark brown to black
	Exit holes	Numerous
	Boring dust	Abundant around base of trees

Table III. Control priorities for SPB in timber based on risk-rating system. (From Thatcher et al, 1982).

Key to spot growth		Spot classification	Risk-rating Points
A.	Stage 1 trees (see Table II)	Absent	0
		Present	30
B.	Stage 1 and 2 trees (See Table II)	1-10	0
		11-20	10
		21-50	20
		More than 50	40
C.	Pine basal area (ft^2/a) (or stand density) at active head or heads of spot	Less than 80 (low density)	0
		80-120 (medium density)	10
		More than 120 (high density)	90
D.	Stand class by average d.b.h. (in inches)	Pulpwood (9 in. or less)	0
		Sawtimber (more than 9 in.)	10

If total is 0-30, control priority is low.
If total is 40-60, control priority is medium.
If total is 70-100, control priority is high.

Table IV. Resistance of pines to SPB attack for major geographic regions of the South. (From Belanger and Malac, 1980).

Levels of resistance	Geographic Region		
	Coastal Plain	Piedmont	Southern Appalachians
Most resistant	Slash Longleaf	Virginia Loblolly	Virginia Eastern White
Least resistant	Shortleaf Loblolly	Shortleaf	Shortleaf Pitch

NATIONAL PARK SERVICE
IPM Information Package

THISTLES

Final Report

30 September 1984

Submitted To:

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U.S. Environmental Protection Agency
Arlington, Virginia 22202

Submitted By:

Dynamac Corporation
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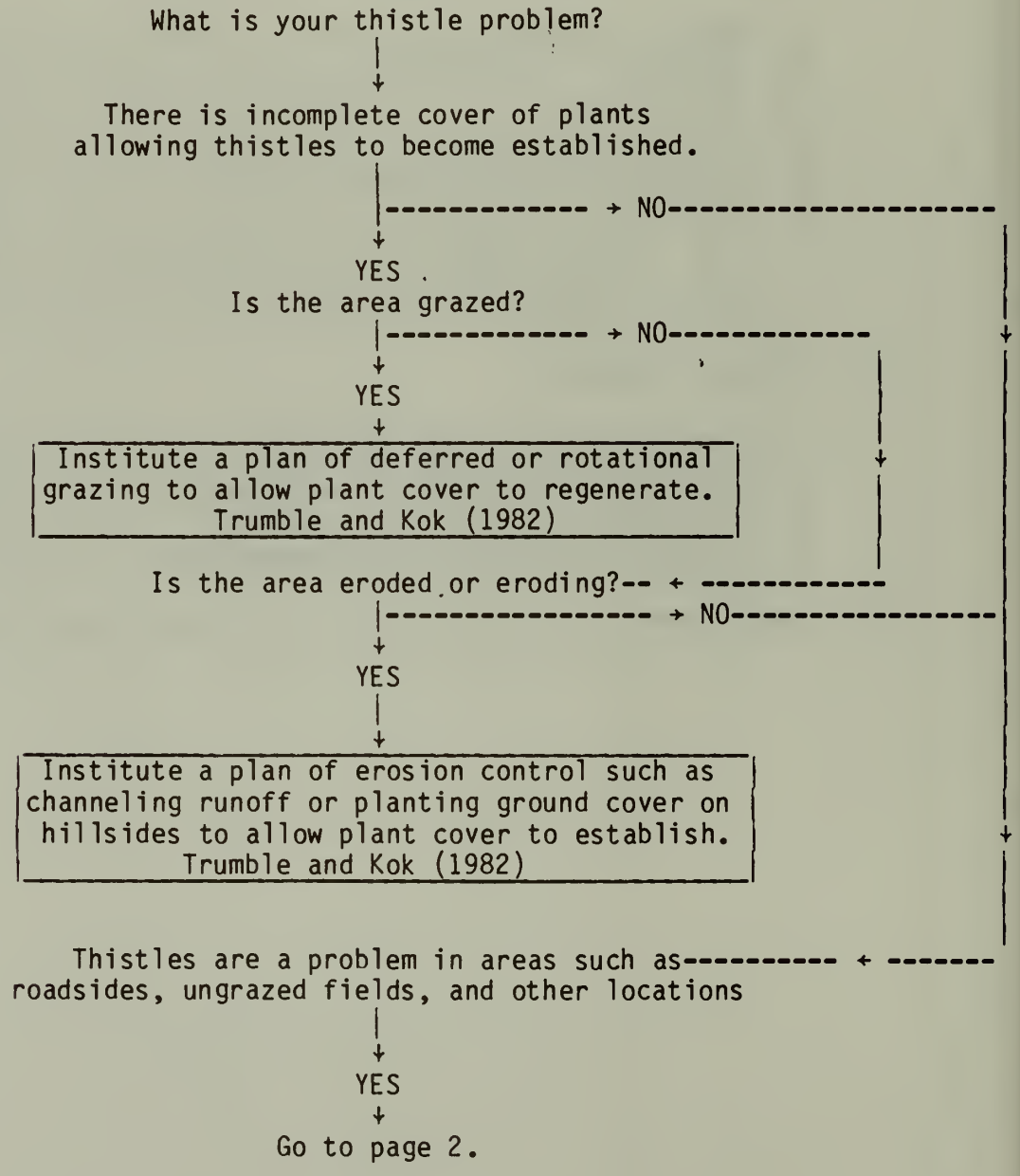
CONTENTS

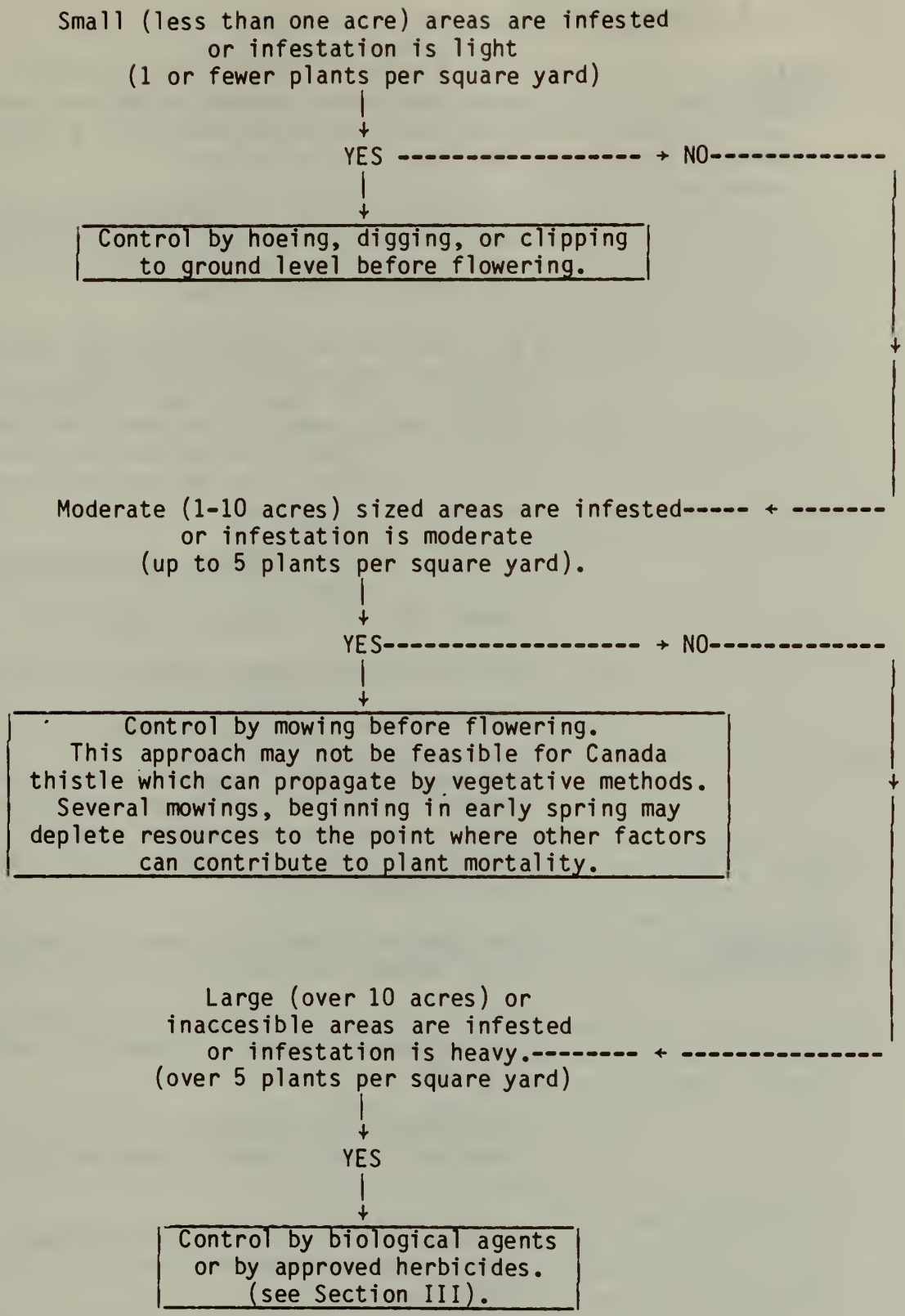
Section		Page
I.	THISTLE IPM DECISION TREE	XXXVI-2
II.	THISTLE BIOLOGY AND ECOLOGY	
	1. Species Described	XXXVI-4
	2. Geographic Distribution	XXXVI-4
	3. Habitat	XXXVI-5
	4. Life Cycles	XXXVI-5
	5. Seasonal Abundance	XXXVI-6
	6. Responses to Environmental Factors	XXXVI-6
	7. Impact of Thistles	XXXVI-6
	7.1. Direct Impact	XXXVI-6
	7.2. Indirect Impact	XXXVI-6
	8. Natural Enemies	XXXVI-6
III.	THISTLE MANAGEMENT	
	1. Population Monitoring Techniques	XXXVI-7
	2. Threshold/Action Population Level	XXXVI-7
	3. Management Alternatives - Nonchemical	XXXVI-7
	4. Management Alternatives - Chemical	XXXVI-11
	5. Summary of Management Recommendations	XXXVI-11
IV.	BIBLIOGRAPHY	XXXVI-13

I. THISTLE IPM DESCISION TREE *

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


What is your thistle problem?
There is incomplete cover of plants allowing thistles to become established.
NO
YES
Is the area grazed?
NO
YES
Institute a plan of deferred or rotational grazing to allow plant cover to regenerate. Trumble and Kok (1982)
Is the area eroded or eroding?
NO
YES
Institute a plan of erosion control such as channeling runoff or planting ground cover on hillsides to allow plant cover to establish. Trumble and Kok (1982)
Thistles are a problem in areas such as roadsides, ungrazed fields, and other locations
YES
Go to page 2.

*Adapted from Trumble and Kok, 1982.


Small (less than one acre) areas are infested
or infestation is light
(1 or fewer plants per square yard)
YES
NO
Control by hoeing, digging, or clipping
to ground level before flowering.
Moderate (1-10 acres) sized areas are infested
or infestation is moderate
(up to 5 plants per square yard).
YES
NO
Control by mowing before flowering.
This approach may not be feasible for Canada
thistle which can propagate by vegetative methods.
Several mowings, beginning in early spring may
deplete resources to the point where other factors
can contribute to plant mortality.
Large (over 10 acres) or
inaccesible areas are infested
or infestation is heavy.
(over 5 plants per square yard)
YES
Control by biological agents
or by approved herbicides.
(see Section III).

II. THISTLE BIOLOGY AND ECOLOGY

1. Species Described:

Five species of thistle are currently considered major pest weed species by NPS and are under chemical, biological, or cultural control programs in North America.

Other species such as Carduus acanthiodes, (plumeless thistle), C. crispus, (welted thistle), and C. macrocephalus, (nodding thistle), may be pest weeds in local areas.

1. Musk thistle - Carduus thoermeri Weinmann Origionally thought to be C. nutans (L.). C. nutans is only found in small isolated pockets (S. Batra, pers. comm.). The musk thistles are a complex of several species and subspecies, the taxonomy of which is unclear. See McCarty and Lamp (1982), for details.

2. Italian thistle - Carduus pycnocephalus L.

3. Canada thistle - Cirsium arvense (L.)

4. Bull thistle - Cirsium vulgare (Savi)Tenore

5. Milk thistle - Silybum marianum (L.)

See Fernald (1950), pages 1538-1542, and Peterson & McKenny (1968), pages 302-306 for descriptive keys and illustrations of thistle species. See also Moore, R.J. and C. Frankton (1974), for detailed keys to species.

2. Geographic Distribution:

The species listed below were introduced from Europe and North Africa into North America.

1. Musk Thistle - Throughout U.S., especially common in Southern California, Midwestern, and Appalachian regions.

2. Italian Thistle - Califronia (mainly in coastal counties), also Midwest. Rare in other areas of U.S..

3. Canada Thistle - Throughout North America except Alas (Most common in northern tier of states and southern Canada.)

4. Bull Thistle - Southern Canada and throughout U.S.

5. Milk Thistle - California, (mainly in coastal counties and drier areas.

Habitat:

Thistles are pioneer species and are most often found in sites where the ground cover or grass cover have been disturbed by grazing, erosion, traffic, or other means. Each plant produces in excess of 10,000 seeds, (some produce as many as 120,000). The fine filaments or pappus (thistle down) of the seed coat permit windborne dispersal over long distances to suitable habitats. Reinfestation of areas occurs from waste places or roadsides where control is not practiced or by long-lived seeds from previous years.

Different species of thistle prefer different soil types:

1. The Carduus thistles on limestone and more fertile soils (Batra, 1982).

2. Bull thistle is predominant on sandy and clay soils.

3. Canada thistle on shale, sandstone or shist soils.

Life Cycles:

Thistles can be divided according to their life cycles in the following manner:

1. Summer annuals, which grow each spring or summer from seed. They grow, mature, produce seeds, and die in one growing season. Seeds generally overwinter before germinating the following spring. Summer annual thistles include Italian thistle.

2. Winter annuals, which germinate in late summer or fall from seed, then mature and produce seed the following spring or summer. Seeds are dormant during the spring. Winter annual thistles include milk thistle.

3. Biennials, which germinate at any time during the growing season. They usually produce a rosette of leaves close to the soil during the first season, then flower (using energy and nutrients stored during the first seasons growth), mature, and die during the next year. Biennial thistles include musk thistle which flowers in May-June, bull thistle which

flowers in July-September, and Italian and milk thistles which may be biennial in dry habitats.

4. Perennials, which become established by seed or vegetative parts (e.g., roots, tubers, or rhizomes). Once established, they live for more than 2 years, and often for many years. Perennial thistles include Canada thistle which flowers in June-October.

5. Seasonal Abundance:

Thistles exhibit foliar growth during the spring, summer, and fall. the amount of growth and rate of new establishment varies from region to region according to geographic, ecological, and climatic characteristics of each region.

6. Response to Environmental Factors:

Any site which is able to support thistle growth will eventually become colonized by species able to utilize available conditions.

Newly germinated thistle seeds require considerable light and usually become established on disturbed areas of pastures or croplands where competition is limited during the seedling stage. (Hodgson, 1968)

7. Impact of Thistles:

7.1 Direct Impact:

Thistles compete for light, water, and nutrients with other, more desireable species.

7.2 Indirect Impact:

Thistles reduce the use of an area for grazing or recreational purposes because of the prominent spines on leaves, stalks, and blooms. Livestock do not eat thistles, and will not graze between thistle plants on more desirable forage. (Batra, 1982).

8. Natural Enemies:

Pest species of thistles have been introduced into North America without their compliment of natural enemies. In Europe, Carduus thistles are attacked by approximately 340 species of insects and 7 fungal pathogens. Current research in biological control is an attempt to reunite natural enemy species with their hosts (see page XXXVI-7).

I. THISTLE MANAGEMENT

Population Monitoring Techniques:

Thistles are relatively conspicuous weeds and periodic visual inspections should be sufficient to monitor thistle populations in most cases.

The permanent plot technique is a good way to monitor thistle populations after they have become established and while they are being controlled. A representative section of the field is marked off and thistles are counted, mapped, and notes made on their condition (height, flowering, etc.). Monitor on a regular basis (weekly, biweekly, monthly). Keep careful records, note when treatments take place, or when biological controls are introduced (naturally or artificially). Study of records, over time, will show population trends and indicate whether or not control strategies are successfull.

A variation on the above is the use of photo plots. Take photographs of the sample plot showing the density of thistles and condition. Include in the photo an object of known size (person, domestic animal, or measuring stick) to indicate thistle size. Also include the date. This method is especially useful in monitoring the effects of control measures over the course of several seasons.

Threshold/ Action Population Levels:

Many states have laws requiring the control or removal of pest thistle species before they flower, whenever and wherever they occur. In these states, and in most other instances, the threshold action level is 1 or more weed thistles. The action level is therefore 1 or more weed thistles observed in an area.

Losses in cultivated crops are as high as 60% at usual levels of infestation (25 shoots of Canada thistle C. arvense per square yard). Pasture losses from Canada thistle at a density of less than 2 shoots per square meter are as high as 15%. (Hodgson, 1968).

Management Alternatives - Nonchemical:

Cultural Controls - In areas which are grazed, eroded, or subject to heavy traffic, the grass cover may not be dense enough to prevent establishment of thistles. Rotational or deferred grazing, water conservation, and erosion control, redirection of traffic, and sound pasture and turf management practices can reestablish heavy grass cover and prevent thistle establishment (Bendall, 1973; Trumble and Kok, 1982).

Grazing management can reduce thistle densities and prevent further invasions by limiting grazing in

spring and throughout the season to promote vigorous growth of perennial grasses and forbes. Early growth left ungrazed outcompetes thistles and lowers infestation levels. Areas left ungrazed in spring may be grazed later in the season.

Mechanical Controls - Cutting or removing thistles (where feasible) can be effective in reducing thistle populations. Musk thistle, if mowed within 2 days of flowering of the terminal blooms, will not produce seed or regenerate significantly. Timing in mowing is important; if mowing occurs 4 days after terminal bloom anthesis (full flowering), significant amounts of seed are produced. Since thistle stands mature at different times, careful monitoring and proper timing are necessary for mowing to be a viable option in an IPM program. However, even if mowing is done late and seed is produced, mowing the stalks will reduce seed dispersal and seed production, keeping infestations from spreading widely (McCarty & Hattling, 1975). Hodgson (1968), reports excellent control in alfalfa fields mowed for hay twice a year.

Canada thistle, due to its ability to propagate vegetatively, is difficult to control by mechanical methods. However, repeated cultivation can significantly reduce infestations if begun when plant reserves are at their lowest stage in early spring (early bud stage), before the shoot leaves can furnish energy to the roots in amounts greater than the roots require for production of new growth.

Cultivation should start in early spring by plowing and disking. When new shoots appear, the area should be cultivated 3-4 inches deep every 20-21 days to destroy new shoots. Up to 90% or more of a Canada thistle infestation can be eliminated in a single season of cultivation when properly performed. Remaining plants can be eliminated by continuing cultivation in the following spring (Hodgson, 1968).

Mechanical controls are compatible with biological controls if the mechanical controls are used early in the season to stress the plants, and allow natural enemies to enter the system to further weaken and eliminate thistles. Mechanical controls combined with chemicals may be successful in some cases. In most cases, however, combining a chemical and biological control is a more viable approach to thistle management.

Controlled burning, unless conducted on a regular basis, may only damage the aboveground portion of the thistle, allowing rapid regrowth from the root section.

Biological Control - Imported weed thistles have been the subject of biological control programs for several years.

Biological control agents seldom eliminate pest thistles from an area, but can reduce populations below set economic thresholds.

Rhinocyllus conicus, a European weevil which feeds on developing seed heads, has been introduced into the U.S. and Canada for control of Carduus thistles, particularly the musk thistle. It has also been introduced for control of Italian and milk thistles in the western U.S. In the absence of Carduus thistles, it will feed on Canada and bull thistles, but control is not as complete as on its primary hosts. R. conicus deposits eggs on bracts and flower stems. Larvae feed beneath developing seeds, destroying them. Pupation occurs in the flowers, and adults emerge in mid-summer. Adults hibernate in overwintering floral rosettes. There is one generation per year.

Trichosirocalus horridus, another European weevil, has also been introduced for control of Carduus thistles. This insect primarily feeds on the root crowns of musk and Italian thistles. T. horridus has been released in Canada and Virginia. It has not been introduced on the West Coast of the U.S. because it has been shown experimentally to feed on artichoke. However, it is not considered to be a pest in artichoke-producing areas of Europe, and further studies are being carried out. T. horridus deposits eggs on leaf ribs, and larvae migrate to the root crown where they feed. Pupation occurs in the soil. Adults feed on emergence, and overwinter in the rosettes. Weevils from populations in southern Europe and from central Europe have been introduced into the U.S. Southern European weevils mate in autumn, oviposit from mid-December to March, and adults emerge in April and June. Central European weevils mate in spring and oviposit in May to June. Adults emerge in September and hibernate until the spring thaw. These two populations (biotypes) are currently undergoing further study to develop more effective control for thistles.

The Cirsium thistles (Canada and bull thistles) are under continuing study for biological controls.

Altica carduorum, a European weevil has been imported into North America for control of Canada thistle. Adults feed throughout the summer on leaves, defoliating the plant, and weakening it. Although Canada thistle is seldom killed outright by this weevil, the continued stress upon it reduces the number and vigor of vegetative shoots and reduces seed production. Although repeatedly released in North America, this species is not yet well established (Batra et al., 1981).

A second weevil, Ceuthorhynchus litura, which feeds on leaves and root crowns is established and providing some control in Canada, Idaho, Montana, and California.

A Tephritid fly, Urophora cardui, which feeds on Canada and bull thistles, was released in 1973 and is established in British Colombia.

Cassida rubiginosa, a Chrysomelid beetle which feeds on leaves of Carduus and Cirsium thistles, has been adventively established in North America since 1927 (Batra et al., 1981).

Several other species of insects, mostly seed-head weevils, are currently being studied for possible importation and release for biological control of thistles in the U.S.

Two fungal pathogens which are spread by thistle feeding insects are also being considered for release in the U.S.:

Rust fungi in the genus Puccinia which attack the leaves of the basal rosette and underground basal parts have been introduced into Canada. Further studies are required to determine their effectiveness.

Ustilago cardui, a smut fungus, has been observed to attack late maturing seed heads of Carduus thistles in Europe. Seed production is stopped in infected plants, giving full control. This fungus compliments control by R. conicus which feeds on early flower heads (Bolt 1978).

Consult your NPS Regional or WASO IPM Coordinator for further information on biological control for thistles in your area.

Management Alternatives - Chemical:

The following herbicides have been used by NPS to control thistles:

Atrazine
2,4-D
Glyphosate
Dicamba

Spot treatments, rather than broadcast, are preferred. Control must be initiated before the plants blossom and produce seeds. Young plants are most susceptible to control with chemicals. Best results are obtained when plants are in their initial and heaviest growth stage.

Trials combining herbicides (usually 2,4-D), and biological control agents (R. conicus and T. horridus) have shown the two to be compatible if precautions are taken (Trumble and Kok, 1980). Field and laboratory tests have shown that spring application of 2,4-D (when blooms are beginning) provides the most effective thistle control, and causes the fewest adverse effects on thistle weevils; R. conicus adults and T. horridus pupae, the only life stages likely to be exposed to such spraying, are relatively unaffected by the herbicides. Adults of both species will move to unsprayed plants, thus increasing biological control in nearby areas where herbicide treatment is not feasible or economical.

Glyphosate is recommended when selectivity is not requried or where it can be used in a manner that does not affect neighboring non-target plants. Where selectivity is required, 2,4-D or dicamba are recommended. Tests to determine compatibility of biological control agents with herbicides other than 2,4-D are still in the planning stage.

Consult your regional IPM coordinator to determine which pesticide, if any, is best suited to your IPM program.

Summary of Management Recommendations:

1. Use cultural controls to reestablish dense grass or ground cover in order to prevent or reduce thistle establishment.

2. Cut, mow or otherwise remove thistles, if feasible. Thistles should be cut before the flowering of terminal blooms to prevent seed production.

3. Use biological controls, if possible, in your area. Check with Regional or WASO IPM Coordinator for details.

4. Use appropriate herbicides on a spot treatment basis. Time applications to control thistles at prebloom stage and for compatibility with natural enemies.

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NATIONAL PARK SERVICE
IPM Information Package

IMPORTED AND NATIVE FIRE ANTS

Final Report

5 October 1984

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Arlington, Virginia 22202

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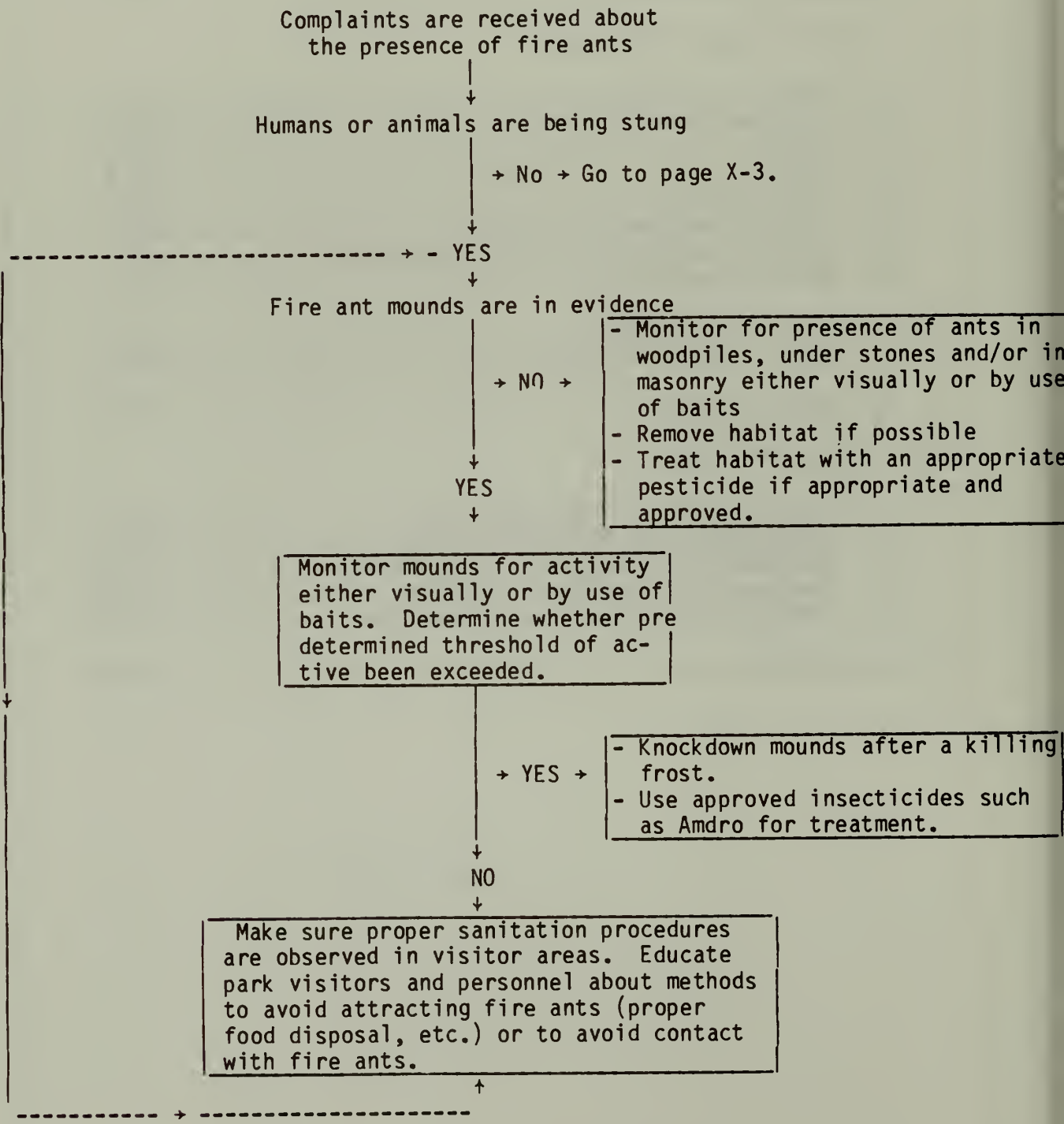
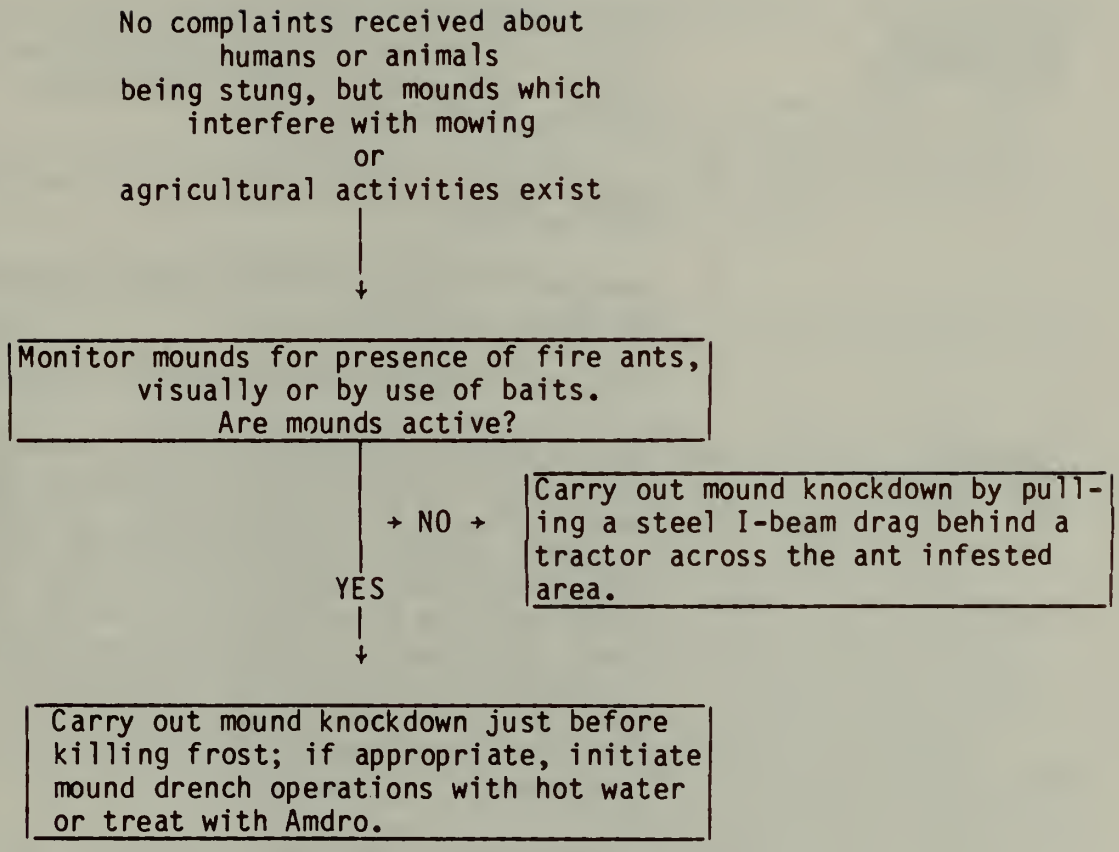
CONTENTS

Section		Page
I.	FIRE ANT DECISION TREE	X-2
II.	FIRE ANT BIOLOGY AND ECOLOGY	
	1. Species Described	X-4
	2. Geographic Distribution	X-4
	3. Habitat	X-4
	4. Hosts	X-5
	5. Life Cycles	X-5
	6. Seasonal Abundance	X-6
	7. Environmental Factors Affecting Survival	X-7
	8. Medical Importance	X-7
	8.1. Direct Effects	X-7
	8.2. Indirect Effects	X-8
	9. Natural Enemies	X-8
III.	FIRE ANT MANAGEMENT	
	1. Population Monitoring Techniques	X-9
	2. Threshold/Action Population Level	X-9
	3. Management Alternatives - Nonchemical	X-11
	4. Management Alternatives - Chemical	X-12
	5. Summary of Management Recommendations	X-13
IV.	BIBLIOGRAPHY	X-14

I. FIRE ANT IPM DECISION TREE

These recommendations represent an approach of minimal pesticide use to maintain pest populations below injurious levels. If additional actions are necessary, consult further with NPS Pest Management Staff. All use of pesticides must conform to Environmental Protection Agency label instructions and be approved on an annual basis by the Director, NPS.


Complaints are received about the presence of fire ants
Humans or animals are being stung
→ No → Go to page X-3.
→ YES
Fire ant mounds are in evidence
→ NO →
- Monitor for presence of ants in woodpiles, under stones and/or in masonry either visually or by use of baits
- Remove habitat if possible
- Treat habitat with an appropriate pesticide if appropriate and approved.
YES
Monitor mounds for activity either visually or by use of baits. Determine whether pre determined threshold of active been exceeded.
→ YES →
- Knockdown mounds after a killing frost.
- Use approved insecticides such as Amdro for treatment.
NO
Make sure proper sanitation procedures are observed in visitor areas. Educate park visitors and personnel about methods to avoid attracting fire ants (proper food disposal, etc.) or to avoid contact with fire ants.


No complaints received about humans or animals being stung, but mounds which interfere with mowing or agricultural activities exist
Monitor mounds for presence of fire ants, visually or by use of baits. Are mounds active?
NO
Carry out mound knockdown by pulling a steel I-beam drag behind a tractor across the ant infested area.
YES
Carry out mound knockdown just before killing frost; if appropriate, initiate mound drench operations with hot water or treat with Amdro.

II. BIOLOGY AND ECOLOGY OF FIRE ANTS

1. Species Described:

   A. Red Imported Fire Ant - *Solenopsis invica* Buren.

   B. Black Imported Fire Ant - *Solenopsis richteri* Forel.

   C. Native Southern Fire Ant - *Solenopsis xyloni* McCook

   D. Native Fire Ant - *Solenopsis germinata* Fabricus.

   See page 119 of U.S. Department of Health, Education and Welfare (1967) for a comparative key to fire ant species.

2. Geographic Distribution

   A. Red Imported Fire Ant - Infests nearly 240 million acres in North Carolina, South Carolina, Tennessee, Georgia, Florida, Alabama, Mississippi, Louisiana, Arizona, and Texas.

   B. Black Imported Fire Ant - Found in northern Mississipp and Louisiana.

   C. Southern Fire Ant - Ranges from California, South Carolina, and Florida.

   D. Fire Ant - Most commonly found in Florida.

3. Habitat:

   A. Red Imported Fire Ant - The most important fire ant pest, it is associated with disturbed habitats, mostly created by man. Abundant in old fields, pastures, lawns, roadsides and many other open sunny habitats. Inhabits fields used for agricultural purposes where its large above ground mounds create problems in planting and harvesting crops. In areas where grass is periodically cut, colonies are flush with the ground and are hard to see. Rarely found in mature forests but is found in those disturbed by fire and storms.

   B. Black Imported Fire Ant - See 3.A. Not a good competitor against the red fire ant. May often be displaced from established habitats by the red fire ant.

   C. Southern Fire Ant - Colonies may be observed as mounds or may be constructed under the cover of stones and other objects. These ants also nest in wood or the masonry of houses.

   D. Fire Ant - Usually nests in mounds constructed around clumps of vegetation but may also nest under objects or in rotting wood.

4. Hosts:

A. Red Imported Fire Ant - A key predator of Heliothis sp. such as the cotton bollworm and tobacco budworm. Also feeds on aphids, beetles and weevils of various types, as well as ticks, horn flies and stable flies. Red fire ants have been known to attack new born rabbits, kill young quail and the young of other ground nesting birds. They have been known to attack new born livestock. Fire ants have been observed eating corn seeds planted close to the soil surface, as well as corn and pine seedlings. Human foods are also consumed.

B. Black Imported Fire Ant - See 4.A. - Shows a preference for foods with high protein content but will also feed on soiled fabric.

C. Southern Fire Ant - Practically omnivorous, feeding on seeds, flesh, juices and fruits of plants, human foods and insects. They have been known to chew insulation off telephone wires.

D. Fire Ant - See 4.C.

5. Life Cycles:

The life cycles of the various fire ant species are very similar.

1. Development of the Individual - Like all ants, the individual fire ant begins life as an egg, which hatches into a legless, grublike larval stage. The larva is a stage specialized for feeding and growing, and almost all growth occurs during this period. As in all insects, growth is accomplished by periodic molting, or shedding of the cuticle (skin). Having reached its final size, the larva becomes a pupa in which various adult structures, such as legs, and in some cases wings, become apparent for the first time. The pupal stage is the transitional stage between the larva and the adult that emerges during the final molt. In insects in general, the adult stage is specialized for reproduction and dispersal, but with ants, some adult individuals are capable of reproduction (queens and males), and the remainder are a sterile worker caste.

2. The Colony - The social unit of fire ants is the colony, and colonies, like individuals, pass through a characteristic life cycle. Fire ants are very typical of ants in general with regard to their life cycle. In addition to workers and a queen, mature

colonies contain males and females capable of flight and reproduction. These are generally termed reproductives. On a warm day following a rain, the workers open holes in the nest through which the reproductives exit on the mating flight. Mating takes place 300 to 800 feet in the air. Mated females descend to the ground, break off their wings and proceed to search for a place to dig the founding nest, a vertical tunnel 2 to 5 inches deep. They seal themselves off in this founding nest to lay eggs and to rear their first brood of workers. They do this entirely without feeding by utilizing reserves stored in their bodies. The first worker brood takes about a month to develop; these are the smallest individuals in the entire colony cycle. They open the nest, begin to forage for food, rear more workers, and care for the queen. Hereafter, the queen essentially becomes an egg-laying machine. The queen generally mates several times and may live for several years. Workers are less long lived and usually will not live for an entire season.

The colony grows rapidly by the production of workers who gradually enlarge the original vertical tunnel into multiple passages and chambers. Eventually most species produce the familiar fire ant mound. Colony maturity is attained when reproductives are once again produced. The reproductives leave to mate and form new colonies. Mature colonies of some species of fire ants may consist of an average 60,000 workers, weighing 70 to 80 grams, but colonies of up to 150,000 or more have been reported.

3. Colony Population - Colonies of several species of fire ants achieve rapid growth by an emphasis on cooperation, rather than competition, during the founding of a new colony. A number of newly mated queens may share in the excavation of the founding nest and in the rearing of the first brood. This cooperation aids in survival during drought or winter.

Colonies of red and black imported fire ants become territorial as they grow; they defend a plot against all other fire ants, and sometimes other ants. Therefo fire ant colony populations will reach an upper limit depending on the territory size of mature colonies. A typical figure for pasture land seems to be about 20-25 mounds per acre (Tschinkel, 1982).

6. Seasonal Abundance:

A. Red Imported Fire Ant - This ant is a tropical ant (imported originally from Brazil) and lacks a true hibernation period. However, there is a seasonal nature to colony life, probably brought on by

seasonal fluctuations of temperature and rainfall in the U.S. Production of reproductives (and therefore the potential for founding of new colonies) has been found to peak in May, June and July in Florida, with the greatest numbers produced in June (Morrill, 1974). Few reproductives are produced between September and March.

B. Black Imported Fire Ant - This ant has its major region of origin in Argentina. No information about seasonal population fluctuations could be found.

C. Southern Fire Ant - Males and females of this native ant have been seen making nuptual flights only in May and June.

D. Fire Ant - See 6.C.

Environmental Factors Affecting Survival:

A. Red Imported Fire Ant - The range of the imported fire ant appears to be limited by temperature and moisture. Pimm and Bartell (1980) studied the climatic characteristics of the areas into which the fire ant spread between 1965 and 1976, and noted that the spread was mostly into warmer, drier regions. There was only a small spread into cooler, wetter regions, indicating the northward spread has reached a limit; there was no occupation of cold, dry regions.

Summer rains are necessary for fire ant reproduction (Tschinkel, 1982). Mating flights occur on warm days after rain, so areas with dry summers, such as California, would probably not present suitable habitats.

B. Other Fire Ants - The same factors as presented in 7.A. would probably be important in other fire ant survival in the U.S., except in the case of the Southern fire ant. The reproductive cycle of this ant is not as dependent on rain. It is a major pest in California.

Medical Importance:

8.1 Direct Effects:

In infested areas, fire ant stings occur more frequently than bee, wasp, hornet and yellowjacket stings. Multiple stings are common because individual ants can administer several stings. The sting produces an uncomfortable, burning sensation and usually results in the formation of a pustule within 6-24 hours.

The majority of stings are uncomplicated, but secondary infections may occur if the pustule is broken. Severe infections requiring skin grafting or amputation have been known to occur.

Some people experience a generalized allergic reaction to a fire ant sting. The reaction can include hives, swelling, nausea, vomiting and shock. People exhibiting these symptons after being stung by fire ants should be removed to a medical facility immediately; death can occur in hypersensitive people. In a survey of 156 families in Lowndes County, Georgia 4.5% reported reactions severe enough to require medical attention (Apperson and Adams, 1983).

Individuals who are allergic to fire ant toxins may incur considerable medical costs for desensitization programs and/or hospital costs.

8.2 Indirect Effects: An important indirect effect of the presence of fire ants is fear of being stung. This may cause anxiety in park visitors and personnel and may reduce utilization of sites where fire ants are present.

9. Natural Enemies:

A. Red Imported Fire Ant - The fire ant is beset by a number of natural enemies in its native South America, but most of these were left behind when the ants were imported into the U.S. Certain fungi and arthropods, especially other ant species, prey on the fire ant in Brazil but their introduction into this country is not anticipated.

Some beetles have been found to infest fire ant colonies, but the numbers of ants they destroy is insignificant (Jouvenaz, 1983).

B. Black imported fire ant - The most important enemy of this ant is the red imported fire ant.

C. Southern fire ant - Preyed upon by the Argentine ant.

D. Fire ant - No reports were found in the literature.

II. FIRE ANT MANAGEMENT

. Population Monitoring Techniques:

A. Red Imported Fire Ant - Population monitoring for fire ant control generally consists of determining the number of active mounds in a particular unit area. Wilson et al., (1981) have suggested that any mound where at least three ants were observed after mound disturbance should be considered active. Moderately to heavily infested fields may contain 80-600 active mounds per acre while in some areas only a few active mounds per acre may be found.

Another method of estimating ant populations for comparison studies is by collecting ants attracted to baits in a test area. A small piece of hamburger and a small piece of agar containing 40% honey are individually placed on two small pieces of aluminum foil or in small plastic cups. The two baits are placed on the ground, 1-3 feet apart, at each bait station. Bait stations are placed about 10 yards apart (Wojcik, 1975). The number of ants attracted to the baits per unit time is determined.

Fillman et al. (1983) used the shake bucket technique to monitor fire ant populations on cotton plants. The bucket was operated by giving 5 shakes to the upper 6-8 inches of the plant terminal into the bucket. Ants falling into the bucket were counted immediately. The authors claim that results were more consistent than visual count methods.

B. Other Fire Ants - See 1.A.

Threshold/ Action Population Levels:

A. Red Imported Fire Ant - The threshold population levels for fire ants will vary according to the sites at which they are found.

Residential and Recreational - Because of their intensive use patterns by humans, few active mounds per acre are tolerated. The presence of one active mound per acre probably would indicate the area was suitable for human use; elimination of the single colony should be easy in most cases. Every effort should be made to correlate fire ant populations observed through

the use of monitoring techniques with complaints received from park visitors and personnel. In this way, a complaint threshold level can be established for each park site.

Agricultural - Mounds built by fire ants in fields often interfere with planting and harvesting operations. Not only is equipment damaged or made inoperable by the presence of mounds, but hand harvesters may refuse to enter fields infested by ants. The number of mounds per acre which can be tolerated will depend on the crop in question and mound size and must be determined by the site operator. For example, in soybean fields, densities of 30-40 mounds per acre can cause yield losses of 15% (Lofgren and Adams, 1981). In pastures and hay fields, bales left on the ground overnight attract fire ants and workers who load bales onto trucks can be stung.

Another serious problem for nursery stock owners and users is that stock from areas that have been quarantined because of the presence of fire ants may not be able to be transported into non-quarantined areas, unless it can be certified as fire ant free.

B. Other Fire Ants - See 2.A.

3. Management Alternatives - Non-chemical:

A number of non-chemical techniques for fire ant control exist, but most have not proven to be very suc cessful.

1. Water - Water has been added to individual mounds, with varying degrees of success reported. Water has also been applied as steam, using a steam generator, usually on a cool day. This technique is cumbersome in the field, especially where large numbers of mound are involved (G. Hoddenbach, personal communication). The applicator tends to run a high risk of being stung using these techniques. Flooding or controlled burning of fire ant infested areas has not only prove ineffective, but may actually promote the increase of new colonies (Collins, 1982).

2. Mechanical Disturbance - Dragging, or knocking down, mounds can provide some season long control but only if mounds are dragged just before the first hard free (Wilson et al., 1981). Mounds are destroyed by pulling a steel I-beam drag, weighing about a ton, behind a tractor across the ant-infested area. Destroying mounds during the warm season will not reduce the num of active mounds; ants quickly rebuild their nests.

3. Biological Control - Among the pathogens which infest fire ants in the United States are several species of microsporidia, among them Burenella dimorpha and Thelohania solenopsae (Jouvenaz, 1983). In laboratory studies, species were infected by feeding ants boiled egg yolk wetted with a suspension of spores.

A number of non-specific enemies of fire ants have been evaluated as biocontrol agents. These include a nematode, Neoaplectana carpocapsae Weiser, bacteria, including Bacillus thuringiensis Berliner, B. sphaericus Meyer and Neide, B. larvae White, B. pulvifaciens Katznelson, Serratia marcescens, Pseudomonas aeruginosa, (Schroeter) Migula, and P. chloraphis (Guignard and Savageau) Bergey et al.; fungi, including Beauveria bassiana (Balsamo) Vuillemin and Metarhizium anisopliae (Metschnikoff) Sorokin; various viruses including baculoviruses and iridescent viruses; and a mite, Pyemotes tritici. The most effective of these is N. carpocapsae; one application (10^6 2nd-stage daurlarvae/mound) can inactivate ca. 80% of treated mounds in 90 days. This nematode can be reared cheaply in artificial media and stored for months; however, its use is limited to single mound treatments, and for this purpose degradable chemical toxicants are more efficacious.

The straw itch mite, P. tritici, can also inactivate fire ant mounds. Bruce and LeCato (1980) reared mites in synchronous culture on insect pupae (cigarette beetle, Lasioderma serricorne) and applied ca. 100 ml of pupae to single mounds as the first progeny emerged from the female mites. Three to 10 applications at about 2-week intervals gave 70% control. Practical use of P. tritici for fire ant control must await the development of more efficient methods of mass production and increased effectiveness. Also, P. tritici is frequently regarded as a pest. Proof must be obtained that this mite can be used without risk to those handling it or to people exposed to it after its dispersal.

At this time it appears that infestation of either N. carpocapsae or P. tritici do not spread to nearby mounds; thus, their use would require treatment of each individual fire ant mound.

4. Public Education - Perhaps the most effective measure which can currently be utilized in preventing injury to park visitors and personnel is education. Visitor activities should be directed away from highly infested areas and visitors should be informed about th habits of the pests. Visitor should be encouraged to u proper sanitation procedures so that fire ants are not attracted to such sites as picnic areas. Information about first aid measures to be taken if a person is stung should be made available.

4. Management Alternatives - Chemical:

Before considering chemical alternatives, the NPS regional IPM coordinator should be consulted to determine which pesticide, if any, should be used in a fire ant control program.

A. Conventional Chemicals - A number of compounds are currently registered for control of imported fire ants, and others are being actively field tested. Among the newer of the registered compounds is the product Amdro which may be broadcast by ground or air to pastures, ranges, lawns, turf and nonagricultural lands. Amdro, in a bait formulated on corn cob grits, can also be applied on a mound by mound basis. Amdro (0.88%) at 0.1-0.2 g per mound is applied; a 90% kill rate has been reported (C.S. Lofgren, personal communication).

Those registered compounds which can be used as mound drenches include chlorpyrifos, diazinon and orthene for lawns and recreation areas. The problems with mound drenches are (1) the difficulty of locating small or hidden mounds (2) the need for multiple applications and (3) the necessity of applying the drench when ants are most susceptible (R.J. Sauer, 1982).

Compounds under active development include EL-468, and avermectin B_1, both applied as a ground or aerial broadcast to non-agricultural lands.

It must be pointed out that the effectiveness of pesticides for fire ant control is a controversial issue. In spite of the use of pesticides, the importe fire ant has increased its range greatly over the last 20 years. Tschinkel (1982) states that "large scale, unspecific control programs aid, rather than hinder, the establishment and spread of the fire ant

and accentuate its dominance over native ants." He points out that before imported fire ants can be managed effectively, more knowledge about the interactions among ants, their environment and chemical agents must be developed.

B. Non-Conventional Chemicals - Research on insect growth regulators for control of fire ants is ongoing. Juvenile hormone mimics, which stop the development of immature ant stages, are under development. One of these, Pro-Drone (MV-678), has been registered. Formulated on a corn cob grit, it is fed to the queen who then produces only reproductives, not workers. It has been reported to give good control of imported fire ants; a 95% reduction of ants in 8 months has been reported (G. Bushman, personnal communication).

The use of pheromones in fire ant control has also been examined, since these chemicals offer ways to upset the behavioral balance in fire ant communities. Behavioral chemicals are important in colony founding, egg laying, brood care, and many other functions. Research indicates that certain behavioral chemicals have the potential of being used to make toxic baits more attractive or more specific for fire ant management.

Summary of Management Recommendations:

1. Park visitors and personnel should be directed away from infested areas and encouraged to observe proper sanitation procedures so that fire ants are not attracted to recreational sites.

2. Dragging, or knocking down, mounds just before the first hard freeze, should be examined as a control measure if it is warranted by the situation. Boiling hot water or steam may also be used.

3. Chemical control, using Amdro as an individual mound treatment, may be attempted if other control measures have failed and the use of pesticides has been approved by NPS.

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